CHAPTER 4

FIBER LINE, WIRE ROPE, AND SCAFFOLDING

This chapter presents information on how to use fiber line, wire rope, and timber in rigging and erecting hoisting devices (such as shear legs, tripods, blocks and tackles), and different types of scaffolds and ladders. Formulas are given on how to determine or find the safe working load of these materials.

FIBER LINE

LEARNING OBJECTIVE: Upon completing this section, you should be able to determine the use, breaking strength, and care *officer lines and rope used for rigging.*

Fiber line is made from either natural or synthetic fiber. Natural fibers, which come from plants, include manila, sisal, and hemp. The synthetic fibers include nylon, polyester, and polypropylene.

NATURAL FIBER ROPES

The two most commonly used natural fiber ropes are manila and sisal, but the only type suitable for construction rigging is a good grade of manila. High-quality manila is light cream in color, smooth, clean, and pliable. The quality of the line can be distinguished by varying shades of brown: Number 1 grade is very light in color; Number 2 grade is slightly darker; Number 3 grade is considerably darker. The next best line-making fiber is sisal. The sisal fiber is similar to manila, but it is lighter in color. This type of fiber is only about 80 percent as strong as manila fiber.

SYNTHETIC FIBER ROPES

Synthetic fiber rope, such as nylon and polyester, has rapidly gained wide use by the Navy. It is lighter in weight, more flexible, less bulky, and easier to handle and store than manila line. It is also highly resistant to mildew, rot, and fungus. Synthetic rope is stronger than natural fiber rope. For example, nylon is about three times stronger than manila. When nylon line is wet or frozen, the loss of strength is relatively small. Nylon rope will hold a load even though several stands may be frayed. Ordinarily, the line can be made reusable by cutting away the chafed or frayed section and splicing the good line together.

FABRICATION OF LINE

The fabrication of line consists essentially of three twisting operations. First, the fibers are twisted to the right to form the yarns. Next, the yarns are twisted to the left to form the strands. Finally, the strands are twisted to the right to form the line. Figure 4-1 shows you how the fibers are grouped to form a three-strand line.

The operation just described is the standard procedure, and the resulting product is known as a right-laid line. When the process is reversed, the result is a left-laid line. In either instance, the principle of opposite twists must al ways be observed. The two main reasons for the principle of opposite twists are to keep the line tight to prevent the fibers from unlaying with a load suspended on it and to prevent moisture penetration.

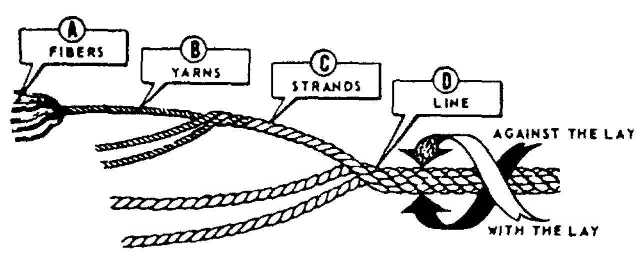

Figure 4-1.—Fiber groupings in a three-strand line.

Types of Line Lays

There are three types of fiber line lays: hawser-laid, shroud-laid, and cable-laid lines. Each type is illustrated in figure 4-2.

Hawser-laid line generally consists of three strands twisted together, usually in a right-hand direction. A shroud-laid line ordinarily is composed of four strands twisted together in a right-hand direction around a center strand, or core, which usually is of the same material, but smaller in diameter than the four strands. You will find that shroud-laid line is more pliable and stronger than hawser-laid line, but it has a strong tendency toward kinking. In most instances, it is used on sheaves and drums. This not only prevents kinking, but also makes use of its pliability and strength. Cable-laid line usually consists of three right-hand, hawser-laid lines twisted together in a left-hand direction. It is especially safe to use in heavy construction work; if cable laid line untwists, it will tend to tighten any regular right-hand screw connection to which it is attached.

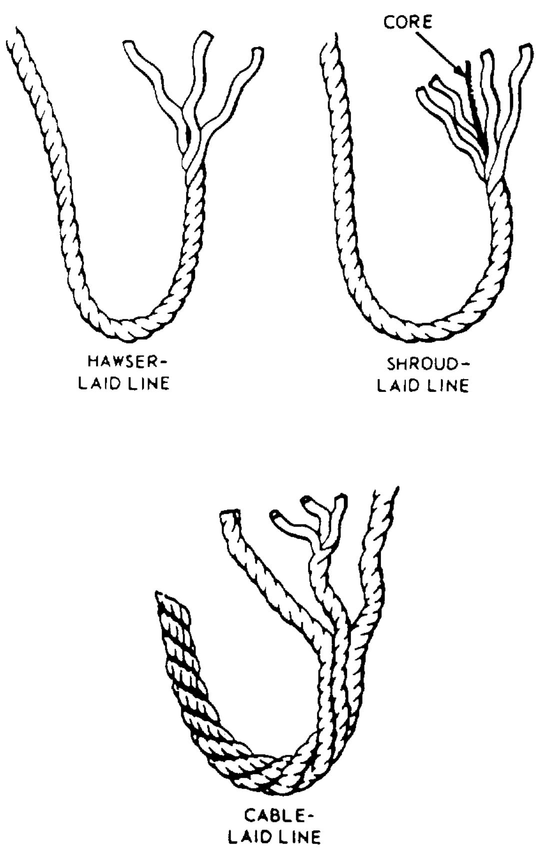

Figure 4-2.—Time type of fiber line.

Size Designation

Line that is 1 3/4 inches or less in circumference is called small stuff this size is usually designated by the number of threads (or yarns) that make up each strand. You may use from 6- to 24-thread strands, but the most commonly used are 9- to 21-thread strands (figure 4-3). You may hear some small stuff designated by name without reference to size. One such type is marline—a tarred, two-strand, left-laid hemp. Marline is the small stuff you will use most for seizing. When you need something stronger than marline, you will use a tarred, three-strand, left-laid hemp called houseline.

Line larger than 1 3/4 inches in circumference is generally size designated by its circumference in inches. A 6-inch manila line, for instance, is constructed of manila fibers and measures 6 inches in circumference. Line is available in sizes ranging up to 16 inches in circumference, but 12 inches is about the largest carried in stock. Anything larger is used only on special jobs.

If you have occasion to order line, you may find that in the catalogs, it is designated and ordered by diameter. The catalog may also use the term “rope” rather than “line.”

Rope yarns for temporary seizing, whippings, and lashings are pulled from large strands of old line that

MANILA LINE

SOME COMMONLY USED SIZES	* CIRCUMFERENCE		THREAD
	INCHES	MILLIMETERS	
	3/4	19.05	6
	1	25.40	9
	1 1/8	28.58	12
	1 1/4	31.76	15
	1 1/2	38.10	21
	1 3/4	44.45	24
	2	50.80	
	3	76.20	
	4	101.6	
	5	127.0	
	6	152.4	

* SIZE IS DESIGNATED BY THE CIRCUMFERENCE

Figure 4-3.—Some commonly used sizes of manila line.

has outlived its usefulness. Full your yarn from the middle, away from the ends, or it will get fouled.

STRENGTH OF FIBER LINE

Overloading a line poses a serious threat to the safety of personnel, not to mention the heavy losses likely to result through damage to material. To avoid overloading, you must know the strength of the line with which you are working. This involves three factors: breaking strength, safe working load (swl), and safety factor.

Breaking strength refers to the tension at which the line will part when a load is applied. Breaking strength has been determined through tests made by rope manufacturers, who provide tables with this information. In the absence of manufacturers' tables, a rule of thumb for finding the breaking strength of manila line using the formula: $C^2 \times 900$ = BS. C equals the circumference in inches, and BS equals the breaking strength in pounds. To find BS, first square the circumference; you then multiply the value obtained by 900. With a 3-inch line, for example, you will get a BS of 8,100, or 3 x 3 x 900= 8,100 pounds.

The breaking strength of manila line is higher than that of sisal line. This is caused by the difference in strength of the two fibers. The fiber from which a particular line is constructed has a definite bearing on its breaking strength. The breaking strength of nylon line is almost three times that of manila line of the same size.

The best rule of thumb for the breaking strength of nylon is BS = C^2x 2,400. The symbols in the rule are the same as those for fiber line. For 2 1/2-inch nylon line, BS = 2.5 x 2.5 x 2,400= 15,000 pounds.

Briefly defined, the safe working load of a line is the load that can be applied without damaging the line. Note that the safe working load is considerably less than the breaking strength. A wide margin of difference between breaking strength and safe working load is necessary. This difference allows for such factors as additional strain imposed on the line by jerky movements in hoisting or bending over sheaves in a pulley block.

You may not always have a chart available to tell you the safe working load for a particular size line. Here is a rule of thumb that will adequately serve your needs on such an occasion: swl = C^2 **x** 150. In this equation, swl equals the safe working load in pounds, and C equals the circumference of the line in inches. Simply take the circumference of the line, square it, then multiply by 150. For a 3-inch line, 3 x 3 x 150= 1,350 pounds. Thus, the safe working load of a 3-inch line is equal to 1,350 pounds.

If line is in good shape, add 30 percent to the swl arrived at by means of the preceding rule; if it is in bad shape, subtract 30 percent from the swl. In the example given above for the 3-inch line, adding 30 percent to the 1,350 pounds gives you a safe working load of 1,755 pounds. On the other hand, subtracting 30 percent from the 1,350 pounds leaves you with a safe working load of 945 pounds.

Remember that the strength of a line decreases with age, use, and exposure to excessive heat, boiling water, or sharp bends. Especially with used line, these and other factors affecting strength should be given careful consideration and proper adjustment made in determining the breaking strength and safe working load capacity of the line. Manufacturers of line provide tables that show the breaking strength and safe working load capacity of line. You will find such tables very useful in your work. You must remember, however, that the values given in manufacturers' tables only apply to new line being used under favorable conditions. For that reason, you must progressively reduce the values given in manufacturers' tables as the line ages or deteriorates with use.

Keep in mind that a strong strain on a kinked or twisted line will put a permanent distortion in the line. Figure 4-4 shows what frequently happens when pressure is applied to a line with a kink in it. The kink that could have been worked out is now permanent, and the line is ruined.

The safety factor of a line is the ratio between the breaking strength and the safe working load. Usually, a safety factor of 4 is acceptable, but this is not always the case. In other words, the safety factor varies depending on such things as the condition of the line and circumstances under which it is to be used. Although the safety factor should never be less than 3, it often must be well above 4 (possibly as high as 8 or

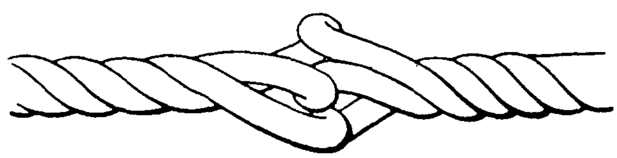

Figure 4-4.—Results of a strong strain on a tine with a kink in it.

10), For best, average, or unfavorable conditions, the following safety factors may often be suitable:

- Best conditions (new line): 4;
- Average conditions (line used, but in good condition): 6; and
- Unfavorable conditions (frequently used line, such as running rigging): 8.

HANDLING AND CARE OF LINES

If you expect the fiber line you work with to give safe and dependable service, make sure it is handled and cared for properly. Study the precautions and procedures given here and carry them out properly.

Cleanliness is part of the care of fiber line. Never drag a line over the deck or ground, or over rough or dirty surfaces. The line can easily pick up sand and grit, which will work into the strands and wear the fibers. If a line does get dirty, use only water to clean it. Do not use soap because it will remove oil from the line, thereby weakening it.

Avoid pulling a line over sharp edges because the strands may break. When you encounter a sharp edge, place chafing gear, such as a board, folded cardboard or canvas, or part of a rubber tire between the line and the sharp edge to prevent damaging the line.

Never cut a line unless you have to. When possible, always use knots that can be untied easily.

Fiber line contracts, or shrinks, when it gets wet. If there is not enough slack in a wet line to permit shrinkage, the line is likely to become overstrained and weakened. If a taut line is exposed to rain or dampness, make sure the line, while still dry, is slackened to allow for the shrinkage.

Line should be inspected carefully at regular intervals to determine whether it is safe. The outside of a line does not show the condition of the line on the inside. Untwisting the strands slightly allows you to check the condition of the line on the inside. Mildewed line gives off a musty odor. Broken strands or yarns usually can be spotted immediately by a trained observer. You will want to look carefully to ensure there is not dirt or sawdust-like material inside the line. Dirt or other foreign matter inside reveals possible damage to the internal structure of the line. A smaller circumference of the line is usually a sure sign that too much strain has been applied to the line.

For a thorough inspection, a line should be examined at several places along its length. **Only one weak spot—anywhere in a line-makes the entire line weak.** As a final check, pull out a couple of fibers from the line and try to break them. Sound fibers show a strong resistance to breakage.

If an inspection discloses any unsatisfactory conditions in a line, make sure the line is destroyed or cut up in small pieces as soon as possible. This precaution prevents the defective line from being used for hoisting.

WIRE ROPE

LEARNING OBJECTIVE: Upon completing this section, you should be able to determine the use, breaking strength, and care of wire rope used for rigging.

During the course of a project, Seabees often need to hoist or move heavy objects. Wire rope is used for heavy-duty work. The characteristics, construction, and usage of many types of wire rope are discussed in the following paragraphs. We will also discuss the safe working load, use of attachments and fittings, and procedures for the care and handling of wire rope.

CONSTRUCTION

Wire rope consists of three parts: wires, strands, and core (figure 4-5). In the manufacture of rope, a number of wires are laid together to form the strand. Then a number of strands are laid together around a core to form the rope.

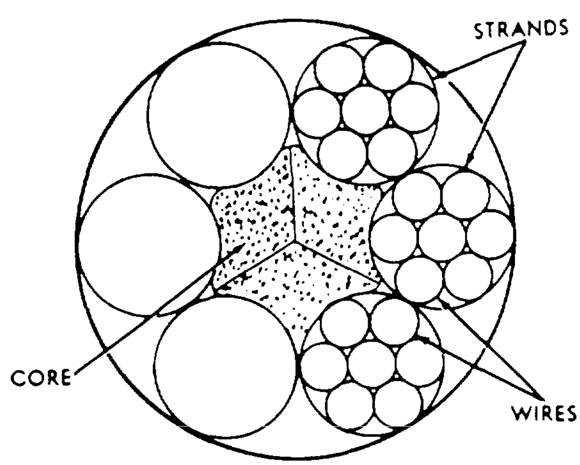

Figure 4-5.—Parts of wire rope.

The basic unit of wire rope construction is the individual wire, which may be made of steel, iron, or other metal in various sizes. The number of wires to a strand varies, depending on the purpose for which the rope is intended. Wire rope is designated by the number of strands per rope and the number of wires per strand. Thus, a 1/2-inch 6-by-19 rope will have 6 strands with 19 wires per strand; but it will have the same outside diameter as a 1/2-inch 6-by-37 wire rope, which will have 6 strands with 37 wires of much smaller size per strand. Wire rope made up of a large number of small wires is flexible, but the small wires are easily broken, so the wire rope does not resist external abrasion. Wire rope made up of a smaller number of larger wires is more resistant to external abrasion but is less flexible.

The core is the element around which the strands are laid to form the rope. It may be a hard fiber (such as manila, hemp, plastic, paper, asbestos, or sisal), a wire strand, or an independent wire rope. Each type of core serves the same basic purpose-to support the strands laid around it.

A fiber core offers the advantage of increased flexibility. Also, it serves as a cushion to reduce the effects of sudden strain and acts as a reservoir for the oil to lubricate the wires and strands to reduce friction between them. Wire rope with a fiber core is used in places where flexibility of the rope is important.

A wire strand core not only resists heat more than a fiber core, but also adds about 15 percent to the strength of the rope. On the other hand, the wire strand makes the rope less flexible than a fiber core.

An independent wire rope core is a separate wire rope over which the main strands of the row are laid. It usually consists of six, seven-wire strands laid around either a fiber core or a wire strand core. This core strengthens the rope more, provides support against crushing, and supplies maximum resistance to heat.

Wire rope maybe made by either of two methods. If the strands or wires are shaped to conform to the curvature of the finished rope before laying up, the rope is termed "preformed." If they are not shaped before fabrication, the rope is termed "nonpreformed." When cut, preformed wire rope tends not to unlay, and it is more flexible than nonpreformed wire rope. Wire nonpreformed wire rope, twisting produces a stress in the wires; and, when it is cut or broken, the stress causes the strands to unlay. **In nonpreformed wire, unlaying is rapid and almost instantaneous, which could cause serious injury to someone not familiar with it.**

The main types of wire rope used by the Navy consist of 6, 7, 12, 19, 24, or 37 wires in each strand. Usually, the rope has six strands laid around a fiber or steel center. Two common types of wire rope, 6-by-19 and 6-by-37 rope, are illustrated in views A and B of figure 4-6, respectively. The 6-by-19 type of rope, having 6 strands with 19 wires in each strand, is commonly used for rough hoisting and skidding work where abrasion is likely to occur. The 6-by-37 wire rope, having 6 strands with 37 wires in each strand, is the most flexible of the standard 6-strand ropes. For that reason, it is particularly suitable when small sheaves and drums are to be used, such as on cranes and similar machinery.

GRADES OF WIRE ROPE

Wire rope is made in a number of different grades. Three of the most common are mild plow steel, plow steel, and improved plow steel.

Mild plow steel rope is tough and pliable. It can stand up under repeated strain and stress, and it has a tensile strength of from 200,000 to 220,000 pounds per square inch (psi). Plow steel wire rope is unusually tough and strong. It has a tensile strength (resistance to lengthwise stress) of 220,000 to 240,000 psi. This rope is suitable for hauling, hoisting, and logging. Improved plow steel rope is one of the best grades of rope available, and most, if not all, of the wire rope in your work will probably be made of this material. It is stronger, tougher, and more resistant to wear than either plow steel or mild plow steel. Each square inch of improved plow steel can withstand a strain of 240,000 to 260,000 psi.

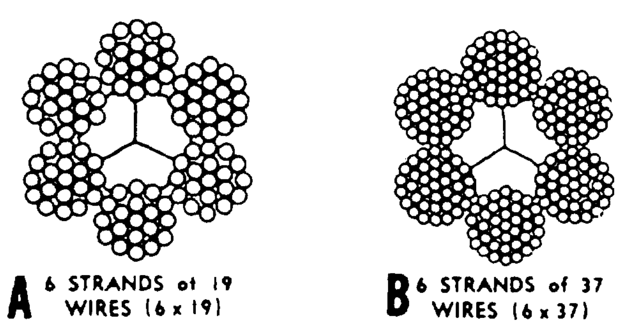

Figure 4-6.—Two common types of wire rope.

MEASURING WIRE ROPE

The size of wire rope is designated by its diameter. The true diameter of a wire rope is the diameter of a circle that will just enclose all of its strands. Correct and incorrect methods of measuring wire rope are illustrated in figure 4-7. In particular, note that the correct way is to measure from the top of one strand to the top of the strand directly opposite it. The wrong way is to measure across two strands side by side. Use calipers to take the measurement. If calipers are not available, an adjustable wrench will do.

To ensure an accurate measurement of the diameter of a wire rope, always measure the rope at three places, at least 5 feet apart. Use the average of the three measurements as the diameter of the rope.

SAFE WORKING LOAD

The term "safe working load" (swl), as used in reference to wire rope, means the load that can be applied and still obtain the most efficient service and also prolong the life of the rope. Most manufacturers provide tables that show the safe working load for their rope under various conditions. In the absence of these tables, you must apply a thumb rule formula to obtain the swl. There are rules of thumb that may be used to compute the strength of wire rope. The one recommended by the Naval Facilities Engineering Command (NAVFAC) is swl (in tons)= $D^2 \times 8$. This particular formula provides an ample safety margin to account for such variables as the number, size, and location of sheaves and drums on which the rope runs. Also included are dynamic stresses, such as the speed of operation and the acceleration and deceleration of the load. All can affect the endurance and breaking strength of the rope.

Let's work an example. In the above formula, D represents the diameter of the rope in inches. Suppose you want to find the swl of a 2-inch rope. Using the formula above, your figures would be: swl = $2^2 \times 8$, or $4 \times 8 = 32$. The answer is 32, meaning that the rope has a swl of 32 tons.

It is very important to remember that any formula for determining swl is only a rule of thumb. In computing the swl of old rope, worn rope, or rope that is otherwise in poor condition, you should reduce the swl as much as 50 percent, depending on the condition of the rope. The manufacturer's data concerning the breaking strength (BS) of wire rope should be used if available. But if you do not have that information, one rule of thumb recommended is BS = $C^2 \times 8{,}000$ pounds.

As you recall, wire rope is measured by the diameter (D). To obtain the circumference (C) required in the formula, multiply D by pi (usually shown by the Greek letter π), which is approximately 3.1416. Thus, the formula to find the circumference is $C = D\pi$.

WIRE ROPE FAILURE

Wire can fail due to any number of causes. Here is a list of some of the common causes of wire rope failure.

- Using the incorrect size, construction, or grade of wire rope;
- Dragging rope over obstacles;
- Having improper lubrication;
- Operating over sheaves and drums of inadequate size;
- Overriding or crosswinding on drums;
- Operating over sheaves and drums with improperly fitted grooves or broken flanges;
- Jumping off sheaves;
- Subjecting it to acid fumes;
- Attaching fittings improperly;
- Promoting internal wear by allowing grit to penetrate between the strands; and
- Subjecting it to severe or continuing overload.

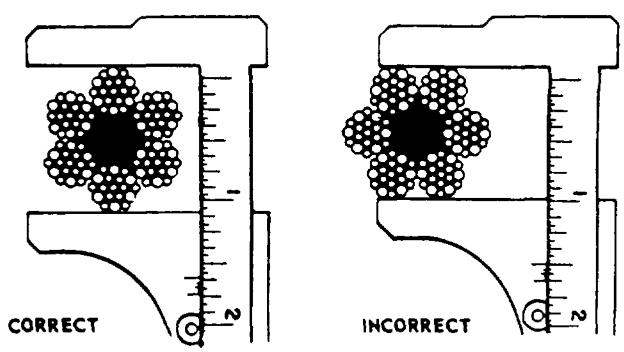

Figure 4-7.—Correct and incorrect methods of measuring wire rope.

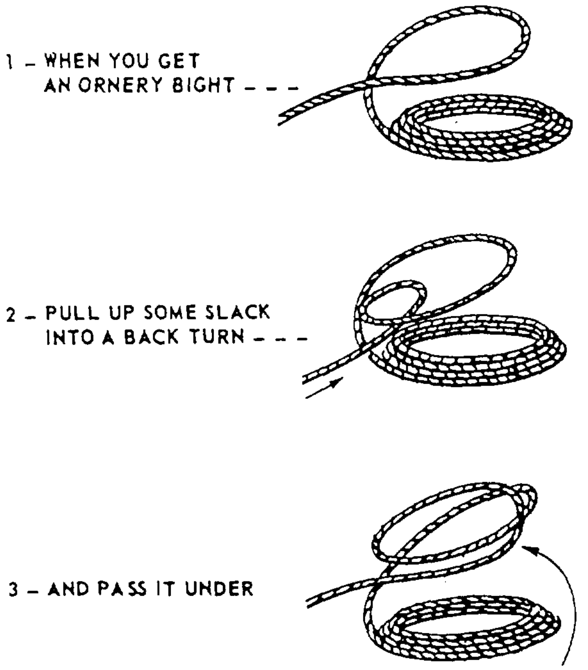

Figure 4-8.—Throwing a back turn to make wire lie down.

HANDLING AND CARE OF WIRE ROPE

To render safe, dependable service over a maximum period of time, wire rope must have the care and upkeep necessary to keep it in good condition. In this section, we'll discuss various ways of caring for and handling wire rope. Not only should you study these procedures carefully, you should also practice them on your job to help you do a better job now. In the long run, the life of the wire rope will be longer and more useful.

Coiling and Uncoiling

Once a new reel has been opened, it may be either coiled or faked down like line. The proper direction of coiling is counterclockwise for left-laid wire rope and clockwise for right-laid rope. Because of the general toughness and resilience of wire, however, it occasionally tends to resist being coiled down. When this occurs, it is useless to fight the wire by forcing down a stubborn turn; it will only spring up again. But if it is thrown in a back turn, as shown in figure 4-8, it will lie down properly. A wire rope, when faked down, will run right off like line; but when wound in a coil, it must always be unwound.

Wire rope tends to kink during uncoiling or unreeling, especially if it has been in service for a long time. A kink can cause a weak spot in the rope, which will wear out quicker than the rest of the rope. A good method for unreeling wire rope is to run a pipe or rod through the center and mount the reel on drum jacks or other supports so the reel is off the ground or deck (figure 4-9.) In this way, the reel will turn as the rope is unwound, and the rotation of the reel will help keep the rope straight. During unreeling, pull the rope straight forward, as shown in figure 4-9, and try to avoid hurrying the operation. As a safeguard against kinking, never unreel wire rope from a stationary reel.

To uncoil a small coil of wire rope, simply stand the coil on edge and roll it along the ground or deck like a wheel or hoop, as illustrated in figure 4-9. Never lay the coil flat on the deck or ground and uncoil it by pulling on the end because such practice can kink or twist the rope.

To rewind wire rope back onto a reel or a drum, you may have difficulty unless you remember that it tends to roll in the direction opposite the lay. For example, a right-laid wire rope tends to roll to the left.

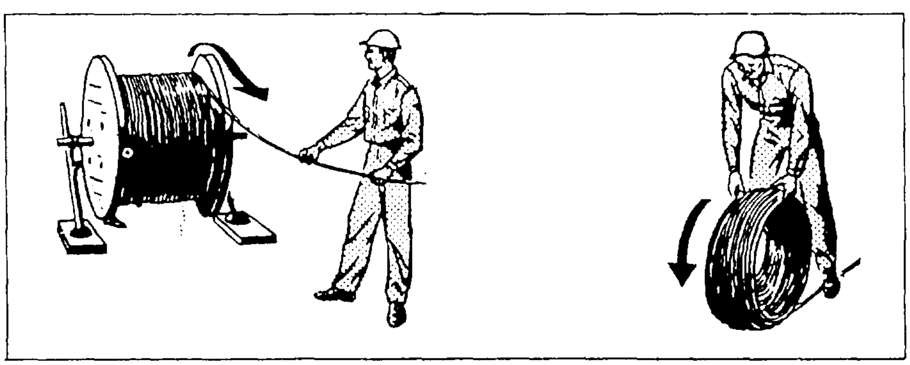

Figure 4-9.—Unreeling wire rope (left) and uncoiling wire rope (right).

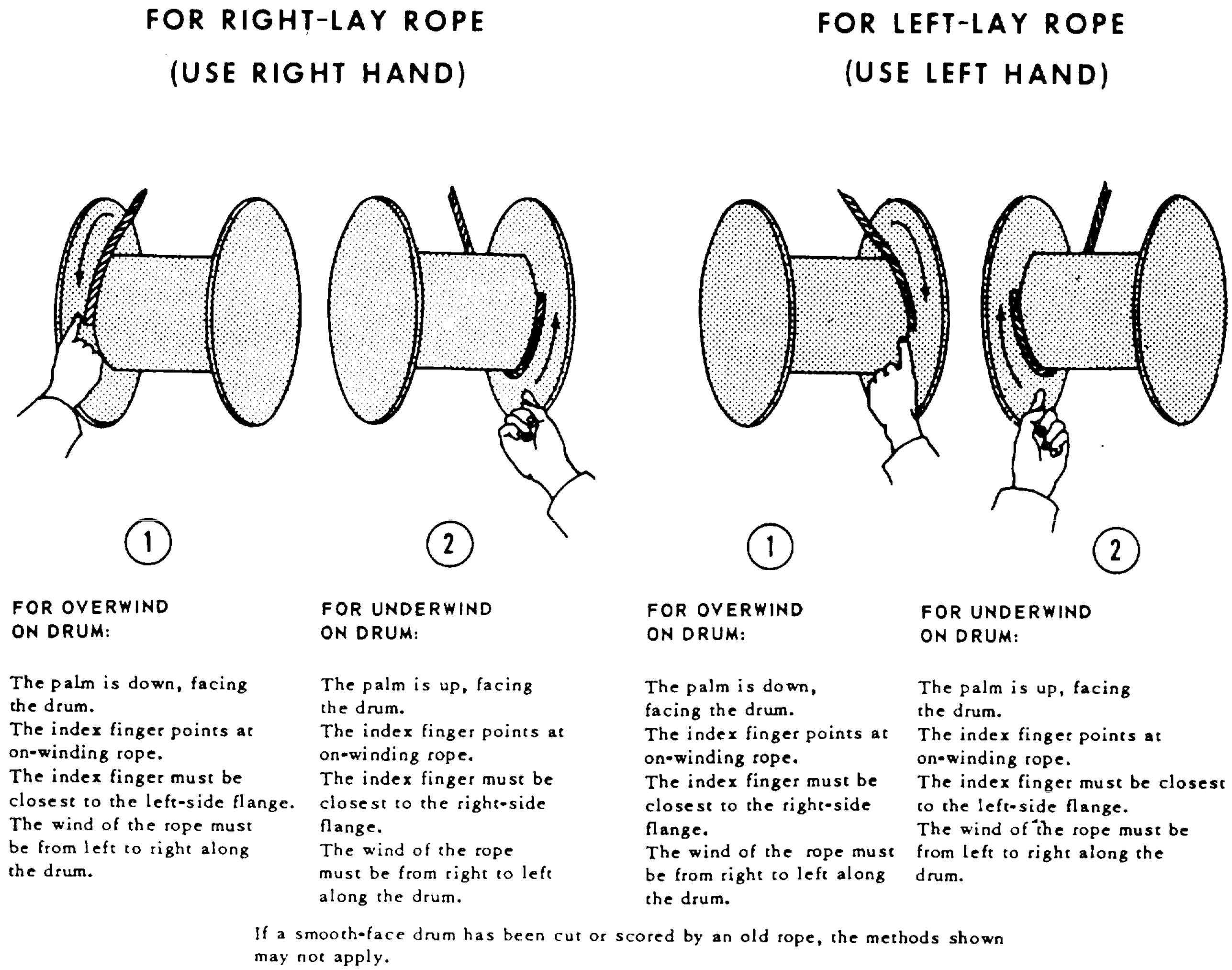

Figure 4-10.—Drum windings diagram for selecting the proper lay of rope.

Carefully study figure 4-10, which shows drum-winding diagrams selecting the proper lay of rope. When putting wire rope onto a drum, you should have no trouble if you know the methods of overwinding and underwinding shown in the illustration. When wire rope is run off one reel onto another, or onto a winch or drum, it should be run from top to top or from bottom to bottom, as shown in figure 4-11.

Kinks

If a wire rope should forma loop, never try to pull it out by putting strain on either part. As soon as a loop is noticed, uncross the ends by pushing them apart. (See steps 1 and 2 in figure 4-12.) This reverses the process that started the loop. Now, turn the bent portion over and place it on your knee or some firm object and push downward until the loop straightens out somewhat. (See step 3 in figure 4-12.) Then, lay the bent portion on a flat surface and pound it smooth with a wooden mallet. (See step 4 in figure 4-12.)

If a heavy strain has been put on a wire rope with a kink in it, the rope can no longer be trusted. Replace the wire rope altogether.

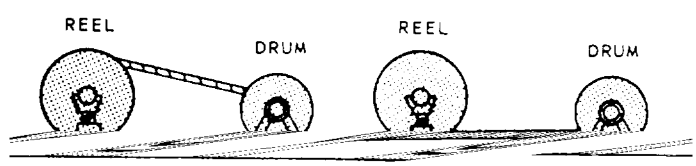

Figure 4-11.—Transferring wire from reel to drum.

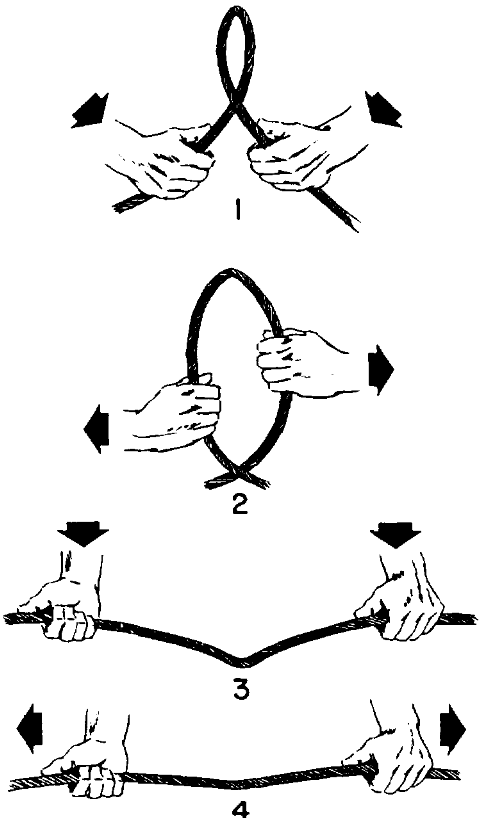

Figure 4-12.—The correct way to takeout a loop in wire rope.

Lubrication

Used wire rope should be cleaned at frequent intervals to remove any accumulation of dirt, grit, rust, or other foreign matter. The frequency of cleaning depends on how much the rope is used. However, rope should always be well cleaned before lubrication. The rope can be cleaned by wire brushes, compressed air, or steam. Do **not use oxygen** in place of compressed air; it becomes very dangerous when it comes in contact with grease or oil. The purpose is to remove all old lubricant and foreign matter from the valleys between the strands and from the spaces between the outer wires. This gives newly applied lubricant ready entrance into the rope. Wire brushing affords a good opportunity to find any broken wires that may otherwise go unnoticed.

Wire rope is initially lubricated by the manufacturer, but this initial lubrication isn't permanent and periodic reapplications have to be made by the user. Each time a wire rope bends and straightens, the wires in the strands and the strands in the rope slide upon each other. To prevent the rope wearing out by this sliding action, a film of lubricant is needed between the surfaces in contact. The lubricant also helps prevent corrosion of the wires and deterioration of fiber centers. A rusty wire rope is a liability! With wire rope, the same as with any machine or piece of equipment, proper lubrication is essential to smooth, efficient performance.

The lubricant should be a good grade of lubricating oil, free from acids and corrosive substances. It must also be of a consistency that will penetrate to the center of the core, yet heavy enough to remain as a coating on the outer surfaces of the strands. Two good lubricants for this purpose are raw linseed oil and a medium graphite grease. Raw linseed oil dries and is not greasy to handle. Graphite grease is highly resistant to saltwater corrosion. Of course, other commercial lubricants may be obtained and used. One of the best is a semiplastic compound that is thinned by heating before being applied. It penetrates while hot, then cools to a plastic filler, preventing the entrance of water.

One method of applying the lubricant is by using a brush. In doing so, remember to apply the coating of fresh lubricant evenly and to work it in well. Another method involves passing the wire rope through a trough or box containing hot lubricant (figure 4-13). In this method, the heated lubricant is placed in the trough, and the rope passed over a sheave, through the lubricant, and under a second sheave. Hot oils or greases have very good penetrating qualities. Upon cooling, they have high adhesive and film strength around each wire.

As a safety precaution, always wipe off any excess when lubricating wire rope. This is especially important where heavy equipment is involved. Too much lubricant can get on brakes or clutches, causing them to fail. While in use, the motion of machinery

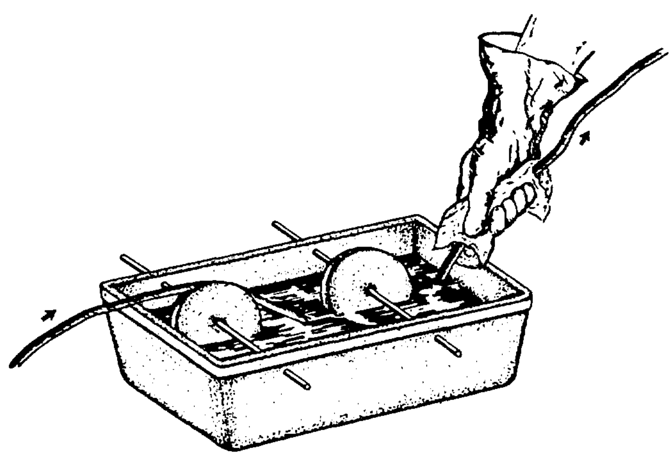

Figure 4-13.—Trough method of lubrication.

can throw excess oil onto crane cabs and catwalks, making them unsafe to work on.

Storage

Wire rope should not be stored in places where acid is or has been kept. The slightest trace of acid coming in contact with wire rope damages it at that particular spot. Many times, wire rope that has failed has been found to be acid damaged. The importance of keeping acid or acid fumes away from wire rope must be stressed to all hands.

It is especially important that wire rope be cleaned and lubricated properly before it is placed in storage. Fortunately, corrosion of wire rope during storage can be virtually eliminated if the lubricant film is applied properly beforehand and if adequate protection is provided from the weather. Bear in mind that rust, corrosion of wires, and deterioration of the fiber core greatly reduce the strength of wire rope. It is not possible to state exactly the loss of strength that results from these effects. It is certainly great enough to require close observance of those precautions prescribed for protection against such effects.

Inspection

Wire rope should be inspected at regular intervals, the same as fiber line. In determining the frequency of inspection, you need to carefully consider the amount of use of the rope and conditions under which it is used.

During an inspection, the rope should be examined carefully for fishhooks, kinks, and worn, corroded spots. Usually, breaks in individual wires are concentrated in those portions of the rope that consistently run over the sheaves or bend onto the drum. Abrasion or reverse and sharp bends cause individual wires to break and bend back. The breaks are known as fishhooks. When wires are only slightly worn, but have broken off squarely and stick out all over the rope, the condition is usually caused by overloading or rough handling. Even if the breaks are confined to only one or two strands, the strength of the rope may be seriously reduced. When 4 percent of the total number of wires in the rope are found to have breaks within the length of one lay of the rope, the wire rope is unsafe. Consider a rope unsafe when three broken wires are found in one strand of 6-by-7 rope, six broken wires in one strand of 6-by-19 rope, or nine broken wires in one strand of 6-by-37 rope.

Overloading a rope also causes its diameter to be reduced. Failure to lubricate the rope is another cause of reduced diameter since the fiber core will dry out and eventually collapse or shrink. The surrounding strands are thus deprived of support, and the rope's strength and dependability are correspondingly reduced. Rope that has its diameter reduced to less than 75 percent of its original diameter should be removed from service.

A wire rope should also be removed from service when an inspection reveals widespread corrosion and pitting of the wires. Particular attention should be given to signs of corrosion and rust in the valleys or small spaces between the strands. Since such corrosion is usually the result of improper or infrequent lubrication, the internal wires of the rope are then subject to extreme friction and wear. This form of internal, and often invisible, destruction of the wire is one of the most frequent causes of unexpected and sudden failure of wire rope. The best safeguard, of course, is to keep the rope well lubricated and to handle and store it properly.

WIRE ROPE ATTACHMENTS

Many attachments can be fitted to the ends of wire rope so that the rope can be connected to other wire ropes, pad eyes, or equipment. The attachment used most often to attach dead ends of wire ropes to pad eyes or like fittings on earthmoving rigs is the wedge socket shown in figure 4-14. The socket is applied to the bitter end of the wire rope, as shown in the figure.

Remove the pin and knock out the wedge first. Then, pass the wire rope up through the socket and

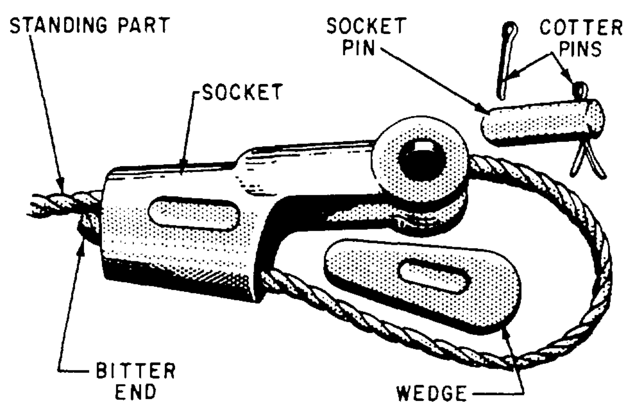

Figure 4-14.—Parts of a wedge socket.

lead enough of it back through the socket to allow a minimum of 6 to 9 inches of the bitter end to extend below the socket. Next, replace the wedge, and haul on the bitter end of the wire rope until the bight closes around the wedge, as shown in figure 4-15. A strain on the standing part will tighten the wedge. You need at least 6 to 9 inches on the dead end (the end of the line that doesn't carry the load). Finally, place one wire rope clip on the dead end to keep it from accidentally slipping back through the wedge socket. The clip should be approximately 3 inches from the socket. Use one size smaller clip than normal so that the threads on the U-bolt are only long enough to clamp tightly on one strand of wire rope. The other alternative is to use the normal size clip and hop the dead end back as shown in figure 4-15. Never attach the clip to the live end of the wire rope.

The advantage of the wedge socket is that it is easy to remove; just take off the wire clip and drive out the wedge. The disadvantage of the wedge socket is that it reduces the strength of wire rope by about 30 percent. Of course, reduced strength means less safe working load.

To make an eye in the end of a wire rope, use new wire rope clips, like those shown in figure 4-16. The U-shaped part of the clip with the threaded ends is called the U-bolt; the other part is called the saddle. The saddle is stamped with the diameter of the wire rope that the clip will fit. Always place a clip with the U-bolt on the bitter end, not on the standing part of the wire rope. If clips are attached incorrectly, the standing part (live end) of the wire rope will be distorted or have mashed spots. An easy way to remember is never saddle a dead horse.

You also need to determine the correct number of clips to use and the correct spacing. Here are two simple formulas.

3 x wire rope diameter + 1 = number of clips

6 x wire rope diameter = spacing between clips

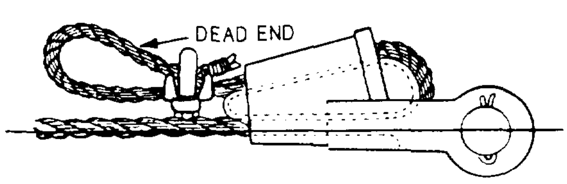

Figure 4-15.—Wedge socket attached properly.

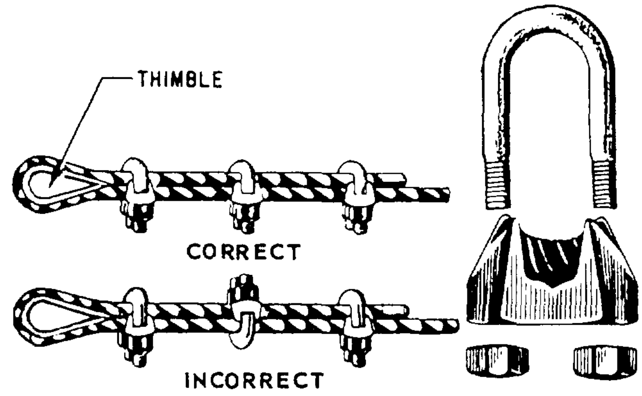

Figure 4-16.—Wire rope clips.

Another type of wire rope clip is the twin-base clip (sometimes referred to as the "universal" or "two-clamp") shown in figure 4-17. Since both parts of this clip are shaped to fit the wire rope, correct installation is almost certain. This considerably reduces potential damage to the rope. The twin-base clip also allows for a clean 360° swing with the wrench when the nuts are being tightened. When an eye is made in a wire rope, a metal fitting (called a thimble) is usually placed in the eye, as shown in figure 4-16, to protect the eye against were. Clipped eyes with thimbles hold approximately 80 percent of the wire rope strength.

After the eye made with clips has been strained, the nuts on the clips must be retightened. Occasional checks should be made for tightness or damage to the rope caused by the clips.

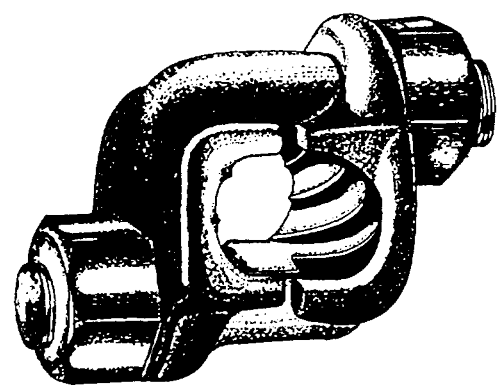

Figure 4-17.—Twin-base wire clip.

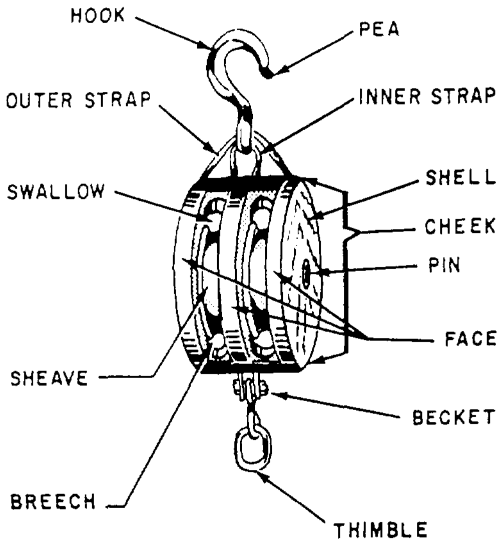

Figure 4-18.—Nomenclature of a fiber line block.

BLOCK AND TACKLE

LEARNING OBJECTIVE: Upon completing this section, you should be able to identify the components and operating characteristics of block and tackle units.

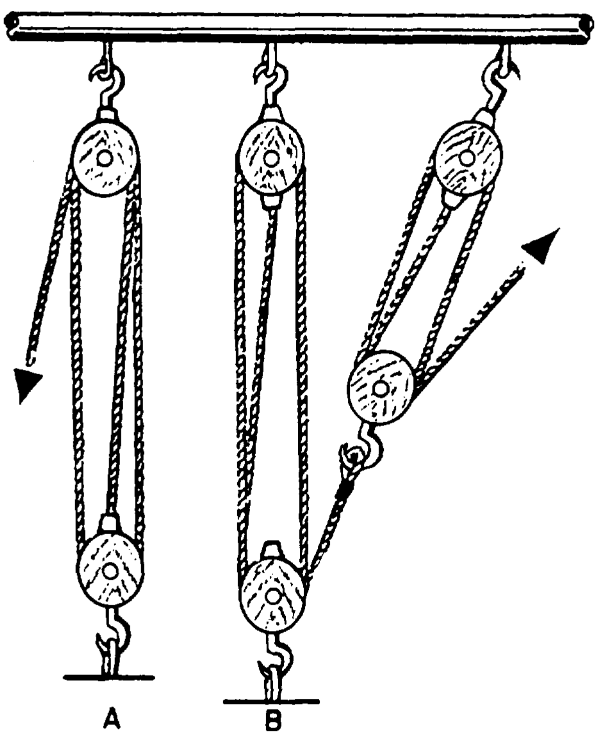

Figure 4-19.—Types of tackle: simple (view A) and compound (view B).

A block (figure 4-18) consists of one or more sheaves fitted in a wood or metal frame supported by a shackle inserted in the strap of the block. A tackle (figure 4-19) is an assembly of blocks and lines used to gain a mechanical advantage in lifting and pulling.

In a tackle assembly, the line is reeved over the sheave(s) of blocks. The two types of tackle systems are simple and compound. A simple tackle system is an assembly of blocks in which a single line is used (view A of figure 4-19). A compound tackle system is an assembly of blocks in which more than one line is used (view B of figure 4-19).

TACKLE TERMS

To help avoid confusion in working with tackle, you need a working knowledge of tackle vocabulary. Figure 4-20 will help you organize the various terms.

A fall is a line, either a fiber line or a wire rope, reeved through a pair of blocks to form a tackle. The hauling part is the part of the fall leading from one of the blocks upon which the power is exerted. The standing part is the end of the fall, which is attached to one of the beckets. The movable (or running) block of a tackle is the block attached to the object to be moved. The fixed (or standing) block is the block attached to a fixed objector support. When a tackle is being used, the movable block moves, and the fixed

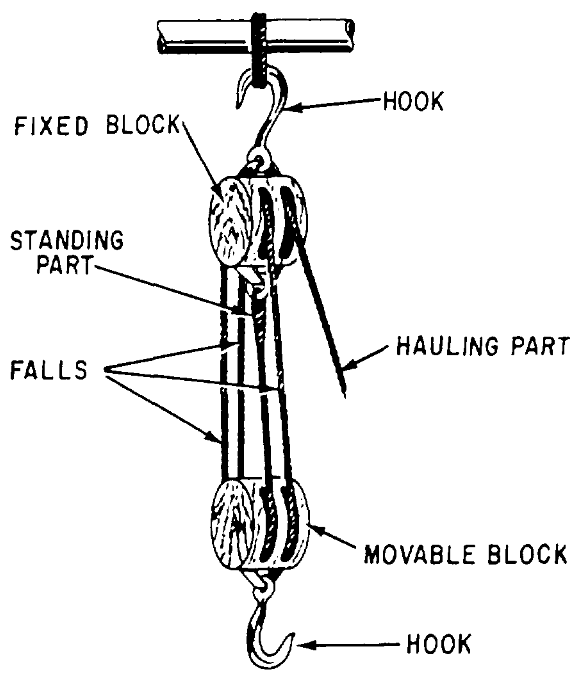

Figure 4-20.—Parts of a tackle.

block remains stationary. The term "two-blocked" means that both blocks of a tackle are as close together as they will go. You may also hear this term called block-and-block. To overhaul is to lengthen a tackle by pulling the two blocks apart. To round in means to bring the blocks of a tackle toward each other, usually without a load on the tackle (opposite of overhaul).

Don't be surprised if your coworkers use a number of different terms for a tackle. For example, line-and-blocks, purchase, and block-and-falls are typical of other names frequently used for tackle.

BLOCK NOMENCLATURE

The block (or blocks) in a tackle assembly changes (or change) the direction of pull or mechanical advantage, or both. The name and location of the key parts of a fiber line block are shown in figure 4-18.

The frame (or shell), made of wood or metal, houses the sheaves. The sheave is a round, grooved wheel over which the line runs. Ordinarily, blocks used in your work will have one, two, three, or four sheaves. Blocks come with more than this number of sheaves; some come with 11 sheaves. The cheeks are the solid sides of the frame, or shell. The pin is a metal axle that the sheave turns on. It runs from cheek to cheek through the middle of the sheave. The becket is a metal loop formed at one or both ends of a block; the standing part of the line is fastened to this part. The straps hold the block together and support the pin on which the sheaves rotate. The swallow is the opening in the block through which the line passes. The breech is the part of the block opposite the swallow.

CONSTRUCTION OF BLOCKS

Blocks are constructed for use with fiber line or wire row. Wire rope blocks are heavily constructed and have a large sheave with a deep groove. Fiber line blocks are generally not as heavily constructed as wire rope blocks and have smaller sheaves with shallower wide grooves. A large sheave is needed with wire rope to prevent sharp bending. Since fiber line is more flexible and pliable than wire rope, it does not require a sheave as large as the same size of wire rope.

Blocks fitted with one, two, three, or four sheaves are often referred to as single, double, triple, and quadruple blocks, respectively. Blocks are fitted with a number of attachments, the number depending upon their use. Some of the most commonly used fittings are hooks, shackles, eyes, and rings. Figure 4-21 shows two metal frame, heavy-duty blocks. Block A is designed for manila line, and block B is for wire rope.

RATIO OF BLOCK SIZE TO LINE OR WIRE SIZE

The size of fiber line blocks is designated by the length in inches of the shell or cheek. The size of standard wire rope blocks is controlled by the diameter of the rope. With nonstandard and special-purpose wire rope blocks, the size is found by measuring the diameter of one of its sheaves in inches.

Use care in selecting the proper size line or wire for the block to be used. If a fiber line is reeved onto a tackle whose sheaves are below a certain minimum diameter, the line will be distorted and will soon wear badly. A wire rope too large for a sheave tends to be pinched and damages the sheave. The wire will also be damaged due to the too short a radius of the bend. A wire rope too small for a sheave lacks the necessary bearing surface, puts the strain on only a few strands, and shortens the life of the wire.

With fiber line, the length of the block used should be about three times the circumference of the

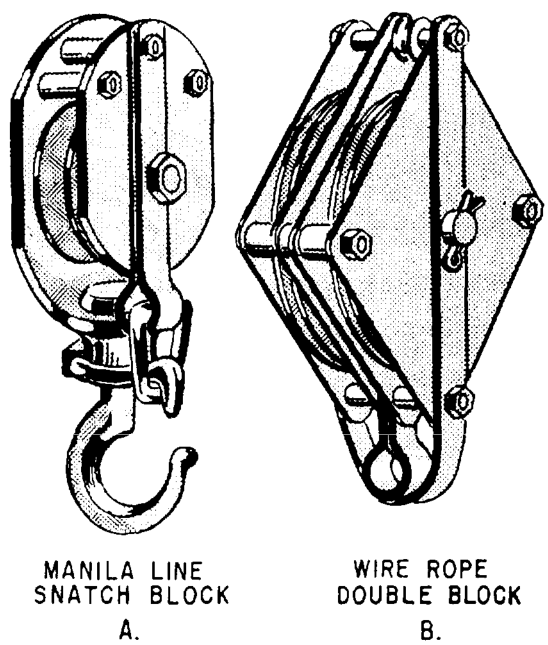

Figure 4-21.—Metal frame, heavy-duty blocks.

line. However, an inch or so either way doesn't matter too much; for example, a 3-inch line may be reeved onto an 8-inch block with no ill effects. As a rule, you are more likely to know the block size than the sheave diameter. However, the sheave diameter should be about twice the size of the circumference of the line used.

Wire rope manufacturers issue tables that give the proper sheave diameters used with the various types and sizes of wire rope they manufacture. In the absence of these, a rough rule of thumb is that the sheave diameter should be about 20 times the diameter of the wire. Remember that with wire rope, it is diameter rather than circumference that is important. Also, remember that this rule refers to the diameter of the sheave rather than to the size of the block.

SNATCH BLOCKS AND FAIRLEADS

A snatch block (figure 4-22) is a single-sheave block made so that the shell opens on one side at the base of the hook to permit a rope or line to be slipped over a sheave without threading the end of it through the block. Snatch blocks ordinarily are used where it is necessary to change the direction of the pull on a line.

Figure 4-23 shows a system of moving a heavy object horizontally away from the power source using snatch blocks. This is an ideal way to move objects in limited spaces. Note that the weight is pulled by a single luff tackle, which has a mechanical advantage of 3 (mechanical advantage is discussed below). Adding snatch blocks to a rigging changes the direction of pull, but the mechanical advantage is not affected. It is, therefore, wise to select the proper rigging system to be used based upon the weight of the object and the type and capacity of the power that is available.

The snatch block that is used as the last block in the direction of pull to the power source is called the leading block. This block can be placed in any convenient location provided it is within 20 drum widths of the power source. This is required because the fairlead angle, or fleet angle, cannot exceed 2° from the center line of the drum; therefore, the 20-drum width distance from the power source to the leading block will assure the fairlead angle. If the fairlead angle is not maintained, the line could jump the sheave of the leading block and cause the line on the reel to jump a riding turn.

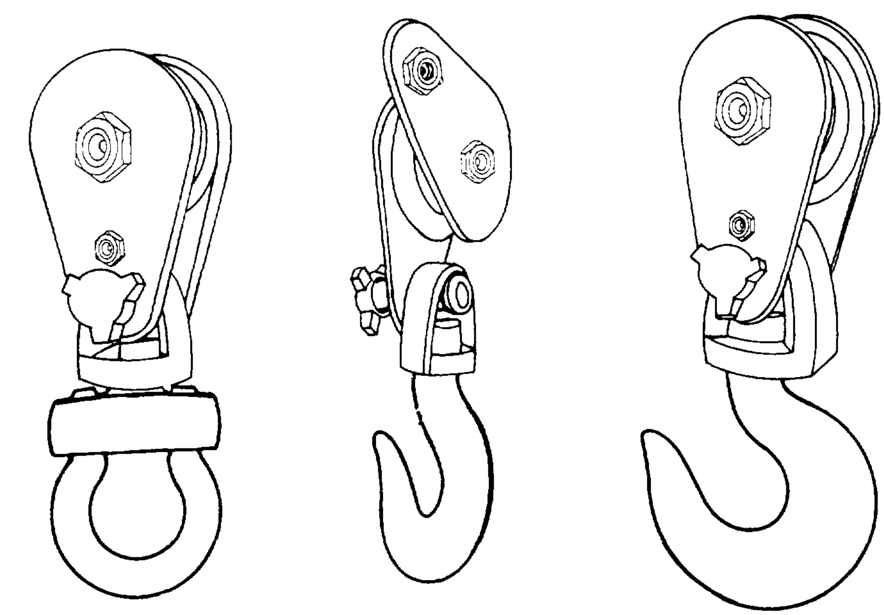

Figure 4-22.—Top dead end snatch blocks.

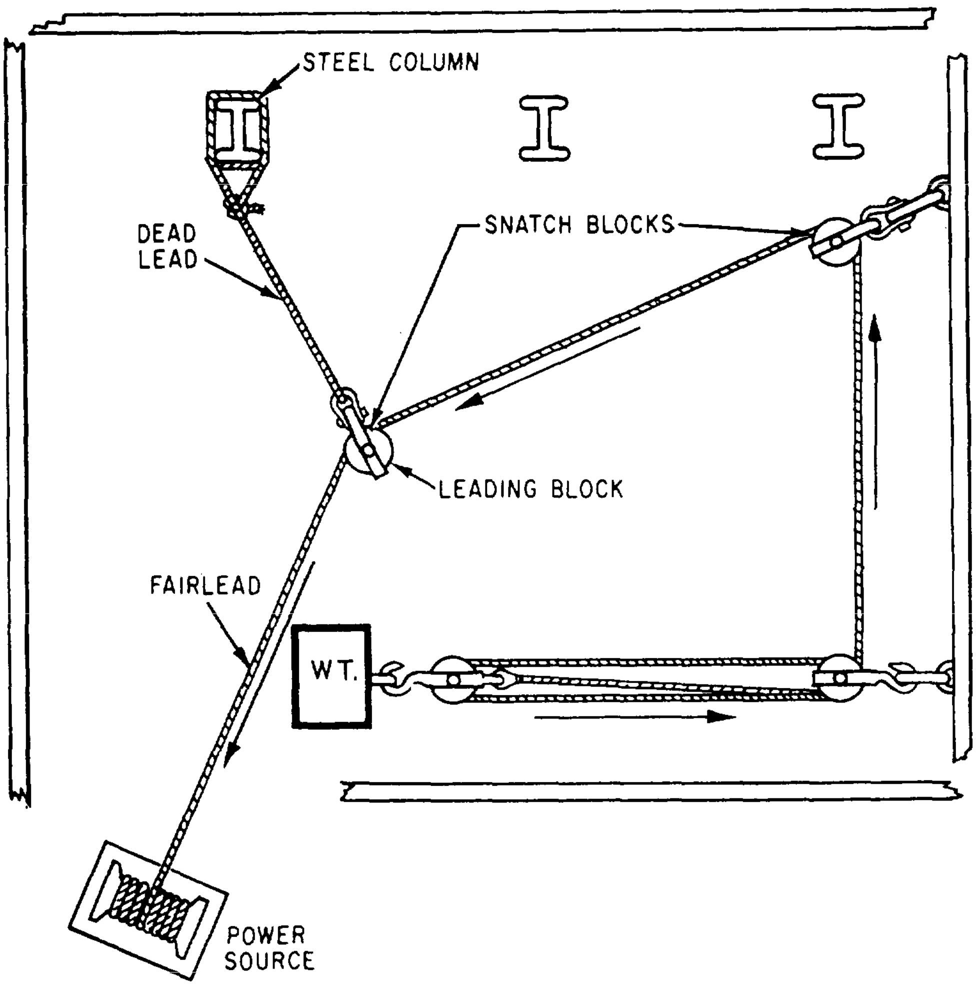

Figure 4-23.—Moving a heavy object horizontally along a floor with limited access using snatch blocks and fairleads.

MECHANICAL ADVANTAGE

The mechanical advantage of a tackle is the term applied to the relationship between the load being lifted and the power required to lift it. If the load and the power required to lift it are the same, the mechanical advantage is 1. However, if a load of 50 pounds requires only 10 pounds to lift it, then you have a mechanical advantage of 5 to 1, or 5 units of weight are lifted for each unit of power applied.

The easiest way to determine the mechanical advantage of a tackle is by counting the number of parts of the falls at the running block. If there are two parts, the mechanical advantage is two times the power applied (disregarding friction). A gun tackle, for instance, has a mechanical advantage of 2. Therefore, lifting a 200-pound load with a gun tackle requires 100 pounds of power, disregarding friction.

To determine the amount of power required to lift a given load by means of a tackle, determine the weight of the load to be lifted and divide that by the mechanical advantage. For example, if it is necessary to lift a 600-pound load by means of a single luff tackle, first determine the mechanical advantage gained by the tackle. By counting the parts of the falls at the movable block, you determine a mechanical advantage of 3. By dividing the weight to be lifted, 600 pounds, by the mechanical advantage in this tackle, 3, we find that 200 pounds of power is required to lift a weight of 600 pounds using a single luff tackle.

Remember though, a certain amount of the force applied to a tackle is lost through friction. Friction develops in a tackle by the lines rubbing against each other, or against the shell of a block. Therefore, an adequate allowance for the loss from friction must be added. Roughly, 10 percent of the load must be allowed for each sheave in the tackle.

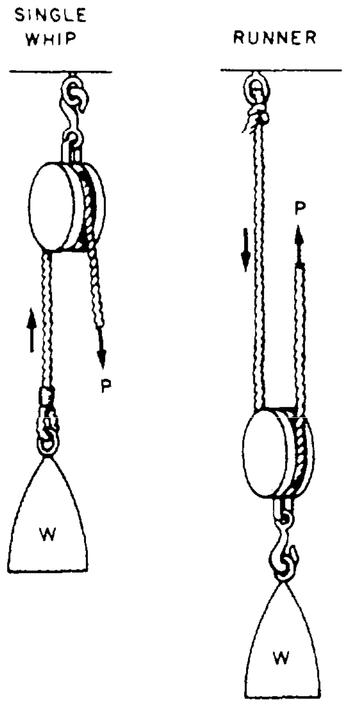

Figure 4-24.—Single-whip and runner tackle.

TYPES OF TACKLE

Tackles are designated in two ways: first, according to the number of sheaves in the blocks that are used to make the tackle, such as single whip or twofold purchase; and second, by the purpose for which the tackle is used, such as yard tackles or stay tackles. In this section, we'll discuss some of the different types of tackle in common use: namely, single whip, runner, gun tackle, single luff, twofold purchase, double luff, and threefold purchase. Before proceeding, we should point out that the purpose of the letters and arrows in figures 4-24 through 4-30 is to indicate the sequence and direction in which the standing part of the fall is led in reeving. You may want to refer to these illustrations when we discuss reeving of blocks in the next sections.

A single-whip tackle consists of one single-sheave block (tail block) fixed to a support with a rope passing over the sheave (figure 4-24.) It has a mechanical advantage of 1. If a 100-pound load is lifted, a pull of 100 pounds, plus an allowance for friction, is required.

A runner (figure 4-24) is a single-sheave movable block that is free to move along the line on which it is reeved. It has a mechanical advantage of 2.

A gun tackle is made up of two single-sheave blocks (figure 4-25). This tackle got its name in the old days because it was used to haul muzzle-loading guns back into the battery after the guns had been fired and reloaded. A gun tackle has a mechanical advantage of 2. To lift a 200-pound load with a gun tackle requires 100 pounds of power, disregarding friction.

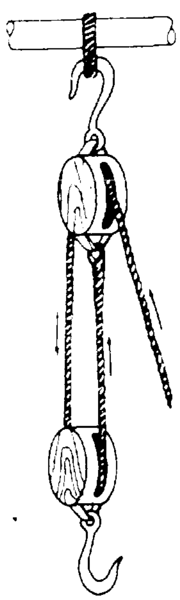

Figure 4-25.—Gun tackle.

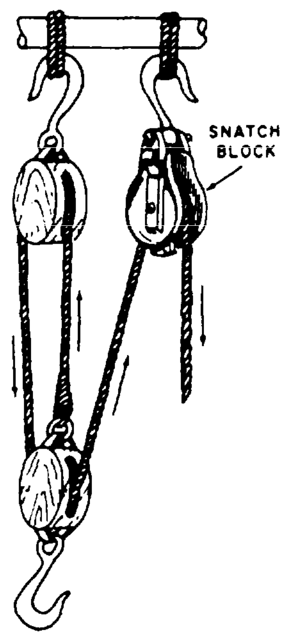

Figure 4-26.—Inverted gun tackle.

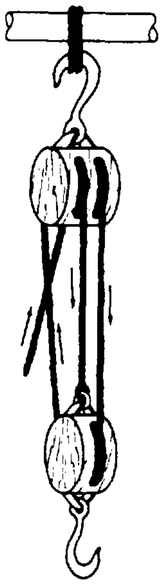

Figure 4-27.—Single-luff tackle.

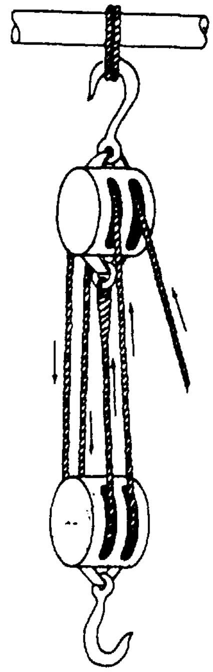

Figure 4-29.—Twofold purchase.

By inverting any tackle, you always gain a mechanical advantage of 1 because the number of parts at the movable block is increased. By inverting a gun tackle, for example, you gain a mechanical advantage of 3 (figure 4-26). When a tackle is inverted, the direction of pull is difficult. This can easily be overcome by adding a snatch block, which changes the direction of the pull, but does not increase the mechanical advantage.

A single-luff tackle consists of a double and single block as indicated in figure 4-27, and the double-luff tackle has one triple and one double

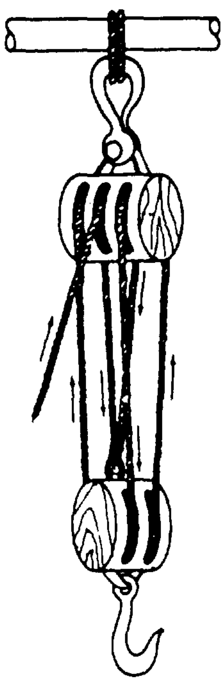

Figure 4-28.—Double-luff tackle.

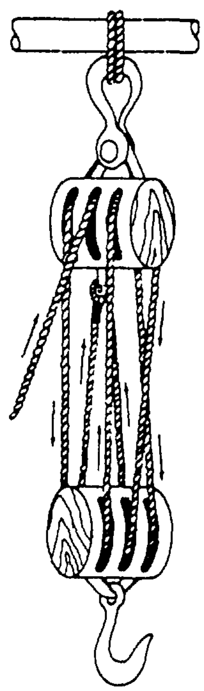

Figure 4-30.—Threefold purchase.

block, as shown in figure 4-28, The mechanical advantage of the single is 3, whereas the mechanical advantage of the double is 5.

A twofold purchase consists of two double blocks, as shown in figure 4-29, whereas a threefold purchase consists of two triple blocks, as shown in figure 4-30. The mechanical advantage of the twofold purchase is 4; the advantage of the threefold is 6.

REEVING TACKLE

In reeving a simple tackle, lay the blocks a few feet apart. The blocks should be placed down with the sheaves at right angles to each other and the becket ends pointing toward each other.

To begin reeving, lead the standing part of the falls through one sheave of the block that has the greatest number of sheaves. If both blocks have the same number of sheaves, begin at the block fitted with the becket. Then, pass the standing part around the sheaves from one block to the other, making sure no lines are crossed, until all sheaves have a line passing over them. Now, secure the standing part of the falls at the becket of the block containing the least number of sheaves, using a becket hitch for a temporary securing or an eye splice for a permanent securing.

With blocks of more than two sheaves, the standing part of the falls should be led through the sheave nearest the center of the block. This method places the strain on the center of the block and prevents the block from toppling and the lines from being cut by rubbing against the edges of the block.

Falls are generally reeved through 8- or 10-inch wood or metal blocks in such a reamer as to have the lower block at right angles to the upper block. Two, three-sheave blocks are the usual arrangement, and the method of reeving these is shown in figure 4-31. The hauling part must go through the middle sheave of the upper block, or the block will tilt to the side and the falls jam when a strain is taken.

If a three- and two-sheave block rig is used, the method of reeving is about the same (figure 4-32), but, in this case, the becket for the dead end must be on the lower, rather than the upper, block.

Naturally, you must reeve the blocks before you splice in the becket thimble, or you will have to reeve the entire fall through from the opposite end.

SAFE WORKING LOAD OF A TACKLE

You know that the force applied at the hauling part of a tackle is multiplied as many times as there

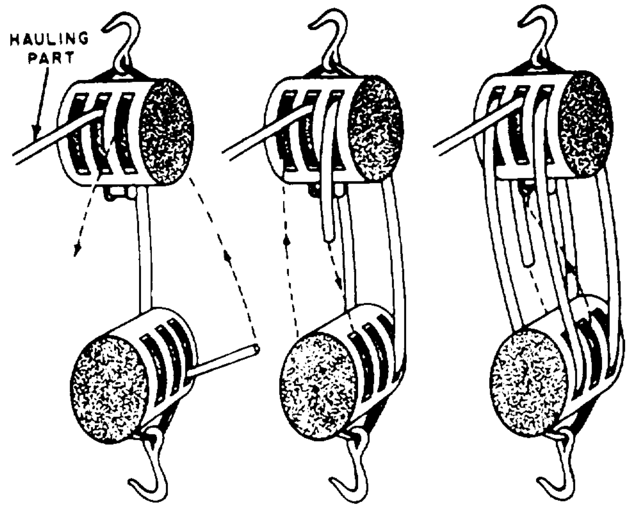

Figure 4-31.—Reeving a threefold purchase.

are parts of the fall on the movable block. Also, an allowance for friction must be made, which adds roughly 10 percent to the weight to be lifted for every sheave in the system. For example, if you are lifting a weight of 100 pounds with a tackle containing five sheaves, you must add 10 percent times 5, or 50 percent, of 100 pounds to the weight in your calculations. In other words, you determine that this tackle is going to lift 150 pounds instead of 100 pounds.

Disregarding friction, the safe working load of a tackle should be equal to the safe working load of the line or wire used, multiplied by the number of parts of the fall on the movable block. To make the necessary

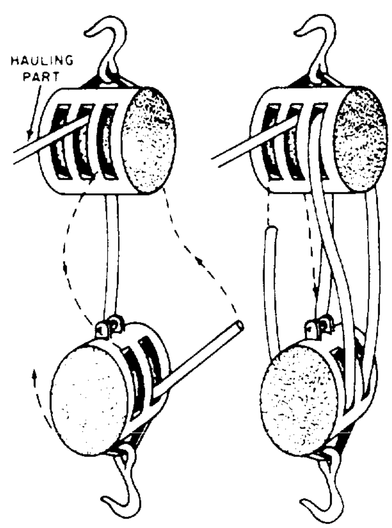

Figure 4-32.—Reeving a double-luff tackle.

allowance for friction, you multiply this result by 10, and then divide what you get by 10 plus the number of sheaves in the system.

Suppose you have a threefold purchase, a mechanical advantage of 6, reeved with a line that has a safe working load of 2 tons. Disregarding friction, 6 times 2, or 12 tons, should be the safe working load of this setup. To make the necessary allowance for friction, however, you first multiply 12 by 10, which gives you 120. This you divide by 10 plus 6 (number of sheaves in a threefold purchase), or 16. The answer is 7 1/2 tons safe working load.

Lifting a Given Weight

To find the size of **fiber** line required to lift a given load, use this formula:

$$C\ (in\ inches) = \sqrt{15 \times P\ (tons)}$$

C in the formula is the circumference, in inches, of the line that is safe to use. The number 15 is the conversion factor. *P* is the weight of the given load expressed in tons. The radical sign, or symbol, over 15 x *P* indicates that you are to find the square root of that product.

To square a number means to multiply that number by itself. Finding the square root of a number simply means finding the number that, multiplied by itself, gives the number whose square root you are seeking. Most pocket calculators today have the square root function. Now, let's determine what size fiber line you need to hoist a 5-ton load. First, circumference equals 15 times five, or C = 15 x 5, or 75. Next, the number that multiplied by itself comes nearest to 75 is 8.6, Therefore, a fiber line 8 1/2 inches in circumference will do the job.

The formula for finding the size of **wire** rope required to lift a given load is: *C (in inches)* = 2.5 x *P (tons)*. You work this formula in the same manner explained above for fiber line. One point you should be careful not to overlook is that these formulas call for the circumference of the wire. You are used to talking about wire rope in terms of its diameter, so remember that circumference is about three times the diameter, roughly speaking. You can also determine circumference by the following formula, which is more accurate than the rule of thumb: circumference equals diameter times pi **(π)**. In using this formula, remember that π equals approximately 3.14.

Size of Line to Use in a Tackle

To find the size of line to use in a tackle for a given load, add one-tenth (10 percent for friction) of its value to the weight to be hoisted for every sheave in the system. Divide the result you get by the number of parts of the fall at the movable block, and use this result as P in the formula

$$C = \sqrt{15 \times P}$$

For example, let's say you are trying to find the size of fiber line to reeve in a threefold block to lift 10 tons. There are six sheaves in a threefold block. Ten tons plus one-tenth for each of the six sheaves (a total of 6 tons) gives you a theoretical weight of 16 tons to be lifted. Divide 16 tons by 6 (number of parts on the movable block in a threefold block), and you get about 2 2/3. Using this as P in the formula you get

$$C = \sqrt{15 \times 2\frac{2}{3}}\ \ or \sqrt{40}\ \ or\ about\ 6.3$$

The square root of 40 is about 6.3, so it will take a line of about 6 1/2 inches in this purchase to hoist 10 tons safely. As you seldom find three-sheave blocks that will take a line as large as 6 1/2 inches, you will probably have to rig two threefold blocks with a continuous fall, as shown in figure 4-33. Each of

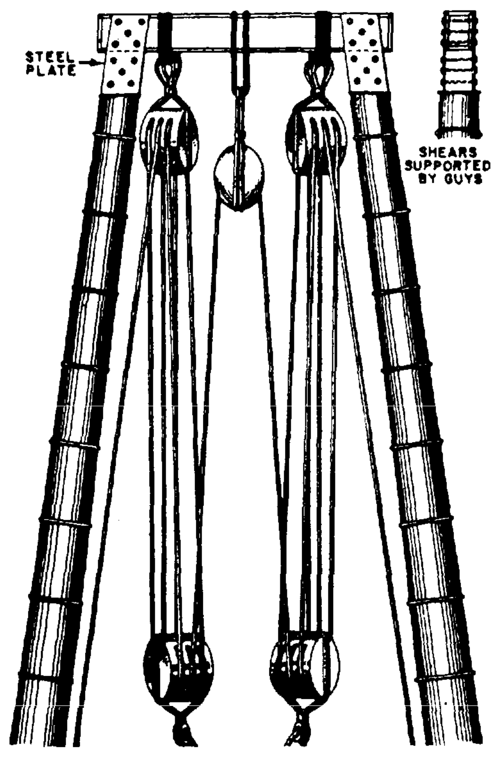

Figure 4-33.—Rigging two tackles with continuous fall.

these will have half of the load. To find the size of the line to use, calculate what size fiber line in a threefold block will lift 5 tons. It works out to about 4 1/2 inches.

TACKLE SAFETY PRECAUTIONS

In hoisting and moving heavy objects with blocks and tackle, stress safety for people and materials.

Always check the condition of blocks and sheaves before using them on a job to make sure they are in safe working order. See that the blocks are properly greased. Also, make sure that the line and sheave are the right size for the job.

Remember that sheaves or drums that have become worn, chipped, or corrugated must not be used because they will damage the line. Always find out whether you have enough mechanical advantage in the amount of blocks to make the load as easy to handle as possible.

Sheaves and blocks designed for use with fiber line must not be used for wire rope since they are not strong enough for that service, and the wire rope does not fit the sheave grooves. Also, sheaves and blocks built for wire rope should never be used for fiber line.

HOOKS AND SHACKLES

Hooks and shackles are handy for hauling or lifting loads without tying them directly to the object with a line or wire rope. They can be attached to wire rope, fiber line, or blocks. Shackles should be used for loads too heavy for hooks to handle.

Hooks should be inspected at the beginning of each workday and before lifting a full-rated load. Figure 4-34, view A, shows where to inspect a hook for wear and strain. Be especially careful during the inspection to look for cracks in the saddle section and at the neck of the hook.

When the load is too heavy for you to use a hook, use a shackle. Shackles, like hooks, should be inspected on a daily routine and before lifting heavy loads. Figure 4-34, view B, shows the area to look for wear.

You should never replace the shackle pin with a bolt. Never use a shackle with a bent pin, and never allow the shackle to be pulled at an angle; doing so will reduce its carrying capacity. Packing the pin with washers centralizes the shackle (figure 4-34, view B).

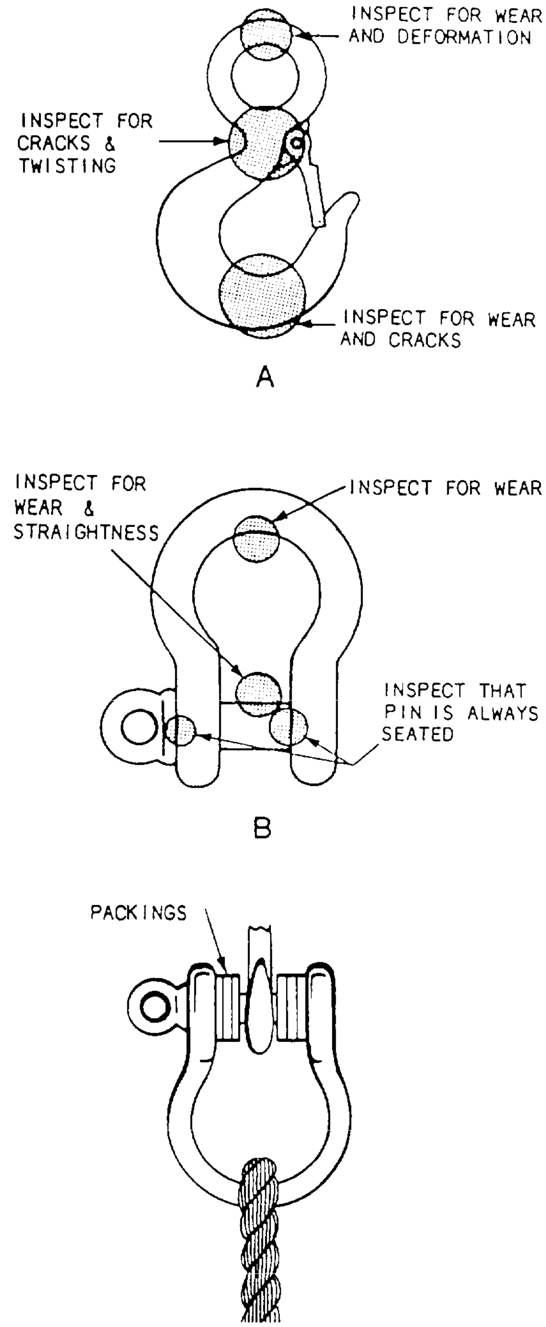

Figure 4-34.—Hook and shackle inspection (views A and B) and packing a shackle with washers.

If you need a hook or shackle for a job, always get it from Alfa Company. This way, you will know that it has been load tested.

Mousing is a technique often used to close the open section of a hook to keep slings, straps, and so on, from slipping off the hook (figure 4-35). To some extent, it also helps prevent straightening of the hook. Hooks may be moused with rope yarn, seizing wire, or a shackle. When using rope yarn or wire, make 8

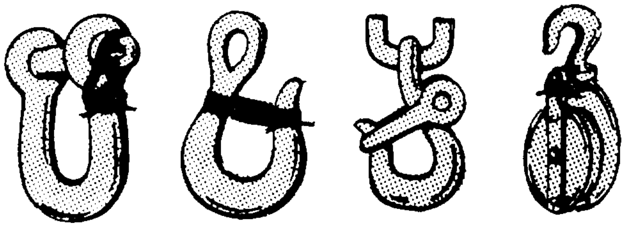

Figure 4-35.—Mousing.

or 10 wraps around both sides of the hook. To finish off, make several turns with the yarn or wire around the sides of the mousing, and then tie the ends securely (figure 4-35).

Shackles are moused when there is danger of the shackle pin working loose and coming out because of vibration. To mouse a shackle, simply take several turns with seizing wire through the eye of the pin and around the bow of the shackle. Figure 4-35 shows what a properly moused shackle looks like.

HOISTING

LEARNING OBJECTIVE: Upon completing this section, you should have a basic understanding of hoisting, handsignals used in lifting loads, and some of the safety rules of lifting.

In lifting any load, it takes two personnel to ensure a safe lift: an equipment operator and a signalman. In the following paragraphs, we will discuss the importance of the signalman and a few of the safety rules to be observed by all hands engaged in hooking on.

SIGNALMAN

One person, and one person only, should be designated as the official signalman for the operator of a piece of hoisting equipment, and both the signalman and the operator must be thoroughly familiar with the standard hand signals. When possible, the signalman should wear some distinctive article of dress, such as a bright-colored helmet. The signalman must maintain a position from which the load and the crew working on it can be seen, and also where he can be seen by the operator.

Appendix III at the end of this TRAMAN shows the standard hand signals for hoisting equipment. Some of the signals shown apply only to mobile equipment; others, to equipment with a boom that can be raised, lowered, and swung in a circle. The two-arm hoist and lower signals are used when the signalman desires to control the speed of hoisting or lowering. The one-arm **hoist** or **lower** signal allows the operator raise or lower the load. To dog off the load and boom means to set the brakes so as to lock both the hoisting mechanism and the boom hoist mechanism. The signal is given when circumstances require that the load be left hanging motionless.

With the exception of the emergency stop signal, which may be given by anyone who sees a necessity for it, and which must be obeyed instantly by the operator, only the official signalman gives the signals. The signalman is responsible for making sure that members of the crew remove their hands from slings, hooks, and loads before giving a signal. The signalman should also make sure that all persons are clear of bights and snatch block lines.

ATTACHING A LOAD

The most common way of attaching a load to a lifting hook is to put a sling around the load and hang the sling on the hook (figure 4-36). A sling can be made of line, wire, or wire rope with an eye in each

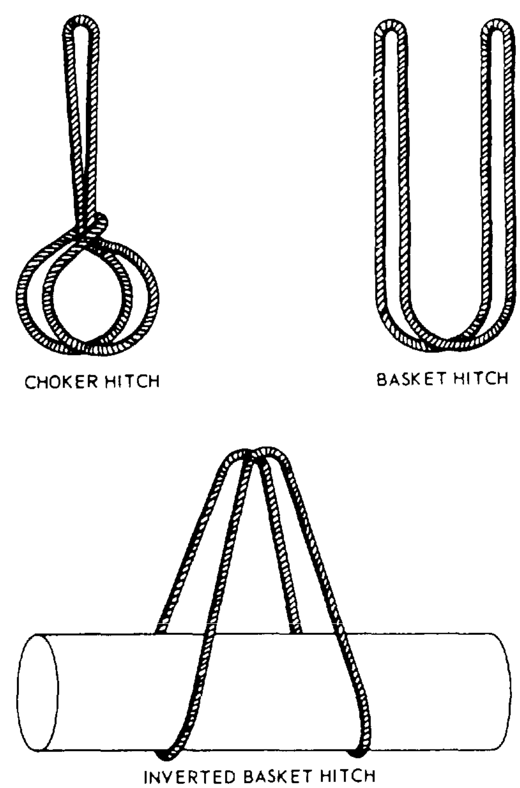

Figure 4-36.—Ways of hitching on a sling.

end (also called a strap) or an endless sling (figure 4-37). When a sling is passed through its own bight or eye, or shackled or hooked to its own standing part, so that it tightens around the load like a lasso when the load is lifted, the sling is said to be choked, or it may be called a choker, as shown in figures 4-36 and 4-37. A two-legged sling that supports the load at two points is called a bridle, as shown in figure 4-38.

SAFETY RULES

The following safety rules must be given to all hands engaged in hooking on. They must be strictly observed.

- The person in charge of hooking on must know the safe working load of the rig and the weight of every load to be hoisted. The hoisting of any load heavier than the safe working load of the rig is absolutely prohibited.
- When a cylindrical metal object, such as a length of pipe, a gas cylinder, or the like, is hoisted in a choker bridle, each leg of the bridle should be given a round turn around the load before it is hooked or shackled to its own part or have a spreader bar placed between the legs. The purpose of this is to ensure that the legs of the bridle will not slide together along the load, thereby upsetting the balance and possibly dumping the load.
- The point of strain on a hook must never be at or near the point of the hook.
- Before the hoist signal is given, the person in charge must be sure that the load will balance evenly in the sling.
- Before the hoist signal is given, the person in charge should be sure that the lead of the whip or falls is vertical. If it is not, the load will take a swing as it leaves the deck or ground.
- As the load leaves the deck or ground, the person in charge must watch carefully for kinked or fouled falls or slings. If any are observed, the load must be lowered at once for clearing.
- Tag lines must be used to guide and steady a load when there is a possibility that the load might get out of control.
- Before any load is hoisted, it must be inspected carefully for loose parts or objects that might drop as the load goes up.
- All personnel must be cleared from and kept out of any area that is under a suspended load, or over which a suspended load may pass.
- Never walk or run under a suspended load.
- Loads must not be placed and left at any point closer than 4 feet 8 inches from the nearest rail

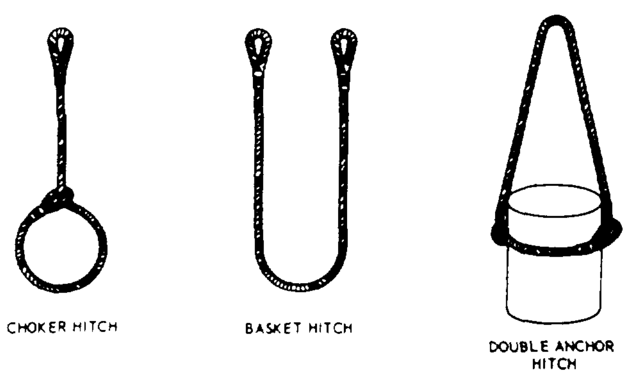

Figure 4-37.—Ways of hitching on straps.

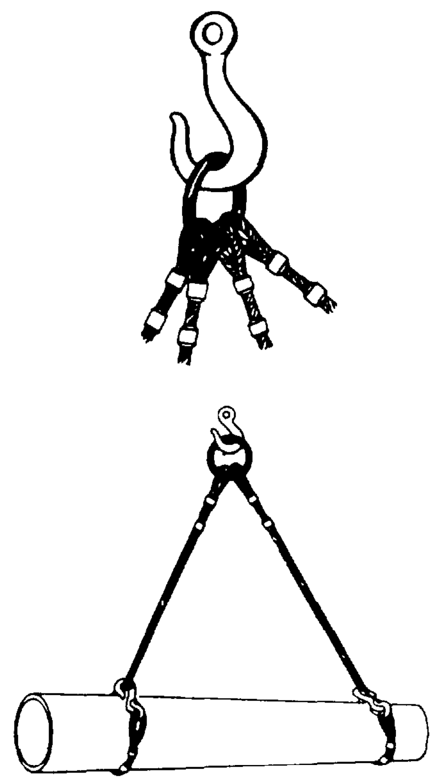

Figure 4-38.—Bridles.

of a railroad track or crane truck, or in any position where they would impede or prevent access to fire-fighting equipment.

- When materials are being loaded or unloaded from any vehicle by crane, the vehicle operators and all other persons, except the rigging crew, should stand clear.
- When materials are placed in work or storage areas, dunnage or shoring must be provided, as necessary, to prevent tipping of the load or shifting of the materials.
- All crew members must stand clear of loads that tend to spread out when landed.
- When slings are being heaved out from under a load, all crew members must stand clear to avoid a backlash, and also to avoid a toppling or a tip of the load, which might be caused by fouling of a sling.

SHEAR LEGS

The shear legs are formed by crossing two timbers, poles, planks, pipes, or steel bars and lashing or bolting them together near the top. A sling is suspended horn the lashed intersection and is used as a means of supporting the load tackle system (figure 4-39). In addition to the name shear legs, this rig often is referred to simply as a "shears". (It has also been called an A-frame.)

The shear legs are used to lift heavy machinery and other bulky objects. They may also be used as end supports of a cableway and highline. The fact that the shears can be quickly assembled and erected is a major reason why they are used in field work.

A shears requires only two guy lines and can be used for working at a forward angle. The forward guy does not have much strain imposed on it during hoisting. This guy is used primarily as an aid in adjusting the drift of the shears and in keeping the top of the rig steady in hoisting or placing a load. The after guy is a very important part of the shears' rigging, as it is under considerable strain when hoisting. It should be designed for a strength equal to one-half the load to be lifted. The same principles for thrust on the spars or poles apply; that is, the thrust increases drastically as the shear legs go off the perpendicular.

In rigging the shears, place your two spars on the ground parallel to each other and with their butt ends even. Next, put a large block of wood under the tops of the legs just below the point of lashing, and place a small block of wood between the tops at the same point to facilitate handling of the lashing. Now, separate the poles a distance equal to about one-third the diameter of one pole.

As lashing material, use 18- or 21-thread small stuff. In applying the lashing, first make a clove hitch around one of the legs. Then, take about eight or nine turns around both legs above the hitch, working towards the top of the legs. Remember to wrap the turns tightly so that the finished lashing will be smooth and free of kinks. To apply the frapping (tight lashings), make two or three turns around the lashing between the legs; then, with a clove hitch, secure the end of the line to the other leg just below the lashing (figure 4-39).

Now, cross the legs of the shears at the top, and separate the butt ends of the two legs so that the spread between them is equal to one-half the height of the shears. Dig shallow holes, about 1 foot (30 cm) deep, at the butt end of each leg. The butts of the legs should be placed in these holes in erecting the shears. Placing the legs in the holes will keep them from kicking out in operations where the shears are at an angle other than vertical.

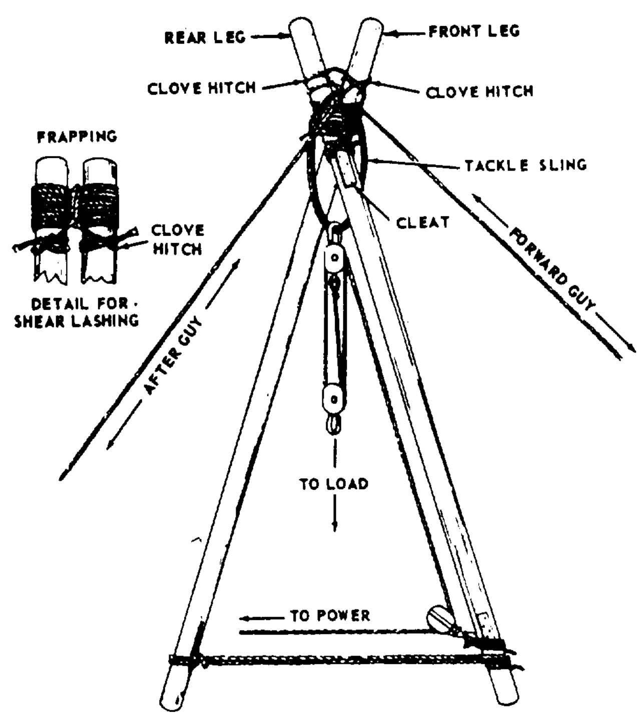

Figure 4-39.—Shear legs.

The next step is to form the sling for the hoisting falls. To do this, take a short length of line, pass it a sufficient number of times over the cross at the top of the shears, and tie the ends together. Then, reeve a set of blocks and place the hook of the upper block through the sling, and secure the hook by mousing the open section of the hook with rope yarn to keep it from slipping off the sling. Fasten a snatch block to the lower part of one of the legs, as indicated in figure 4-39.

The guys—one forward guy and one after guy—are secured next to the top of the shears. Secure the forward guy to the rear leg and the after guy to the front leg using a clove hitch in both instances. If you need to move the load horizontally by moving the head of the shears, you must rig a tackle in the after guy near its anchorage.

TRIPODS

A tripod consists of three legs of equal length that are lashed together at the top (figure 4-40). The legs are generally made of timber poles or pipes. Materials used for lashing include fiber line, wire rope, and chain. Metal rings joined with short chain sections are also available for insertion over the top of the tripod legs.

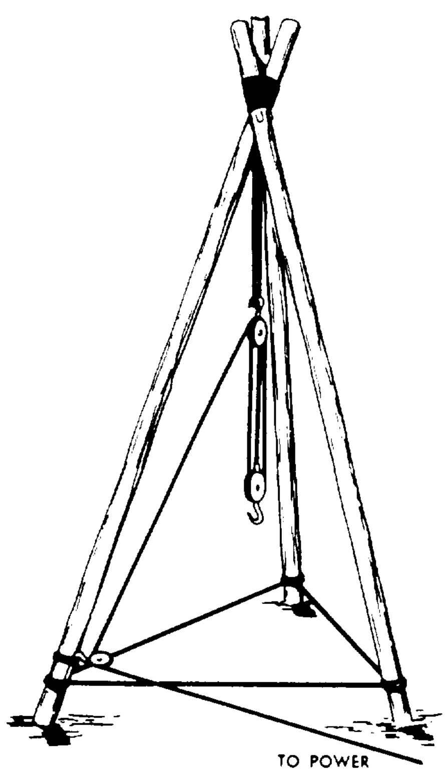

Figure 4-40.—Tripod.

When compared with other hoisting devices, the tripod has a distinct disadvantage: it is limited to hoisting loads only vertically. Its use will be limited primarily to jobs that involve hoisting over wells, mine shafts, or other such excavations. A major advantage of the tripod is its great stability. In addition, it requires no guys or anchorages, and its load capacity is approximately one-third greater than shears made of the same-size timbers. Table 4-1 gives the load-carrying capacities of shear legs and tripods for various pole sizes.

Rigging Tripods

The strength of a tripod depends largely on the strength of the material used for lashing, as well as the amount of lashing used. The following procedure for

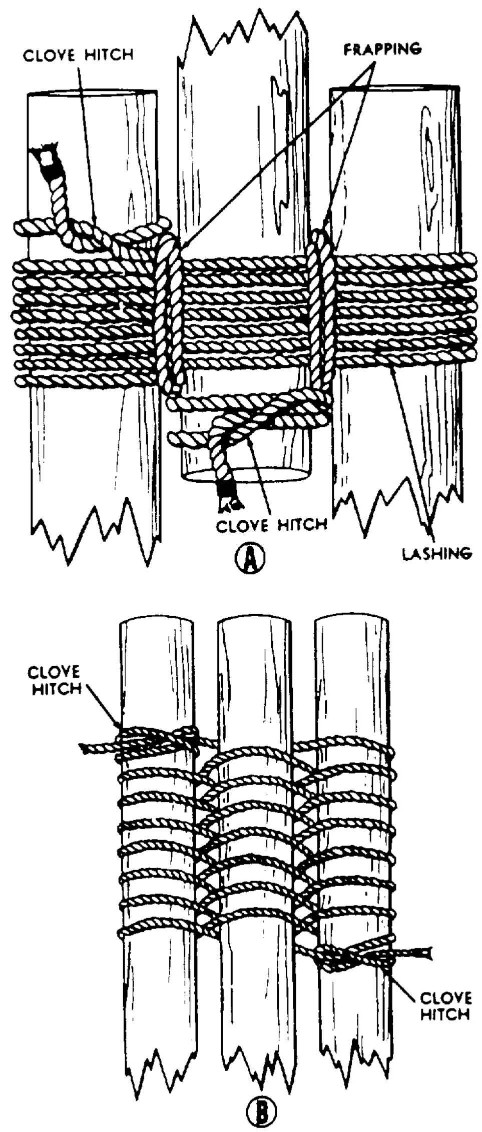

Figure 4-41.—Lashings for a tripod.

Table 4-1.—Load-Carrying Capacities of Shear Legs and Tripods

POLE SIZE (INCHES)	LENGTH (FEET)	WORKING CAPACITY (TONS) SHEAR LEGS (2) POLES	WORKING CAPACITY (TONS) TRIPODS (3) POLES
6 × 6	20 25 30	8 5 3	13 7 5
8 × 8	25 30 40 50	12 8 5 3	18 13 7 5
10 × 10	20 25 30 40 50	35 26 17 10 7	52 39 26 15 10
12 × 12	30 40 50 60	35 21 14 10	52 31 21 15

lashing applies to a line 3 inches in circumference or smaller. For extra heavy loads, use more turns than specified in the procedure given here. For light loads, use fewer turns than specified here.

As the first step of the procedure, take three spars of equal length and place a mark near the top of each to indicate the center of the lashing, Now, lay two of the spars parallel with their tops resting on a skid (or block). Place the third spar between the two, with the butt end resting on a skid. Position the spars so that the lashing marks on all three are in line. Leave an interval between the spars equal to about one-half the diameter of the spars. This will keep the lashing from being drawn too tightly when the tripod is erected.

With the 3-inch line, make a clove hitch around one of the outside spars; put it about 4 inches above the lashing mark. Then, make eight or nine turns with the line around all three spars. (See view A of figure 4-41.) In making the turns, remember to maintain the proper amount of space between the spars.

Now, make one or two close frapping turns around the lashing between each pair of spars. Do not draw the turns too tightly. Finally, secure the end of the line with a clove hitch on the center spar just above the lashing, as shown in view A of figure 4-41.

There is another method of lashing a tripod that you may find preferable to the method just given. It may be used in lashing slender poles up to 20 feet in length, or when some means other than hand power is available for erection,

First, place the three spars parallel to each other, leaving an interval between them slightly greater than twice the diameter of the line to be used. Rest the top of each pole on a skid so that the end projects about 2 feet over the skid. Then, line up the butts of the three spars, as indicated in view B of figure 4-41.

Next, make a clove hitch on one outside leg at the bottom of the position the lashing will occupy, which is about 2 feet from the end. Now, proceed to weave the line over the middle leg, under and around the other outside leg, under the middle leg, over and around the first leg, and so forth, until completing about eight or nine turns. Finish the lashing by forming a clove hitch on the other outside leg (view B of figure 4-41).

ERECTING TRIPODS

In the final position of an erected tripod, it is important that the legs be spread an equal distance apart. The spread between legs must be no more than two-thirds nor less than one-half the length of a leg, Small tripods, or those lashed according to the first procedure given in the preceding section, may be raised by hand. Here are the main steps.

Start by raising the top ends of the three legs about 4 feet, keeping the butt ends of the legs on the ground. Now, cross the tops of the two outer legs, and position the top of the third or center leg so that it rests on top of the cross.

A sling for the hoisting tackle can be attached readily by first passing the sling over the center leg, and then around the two outer legs at the cross. Place the hook of the upper block of a tackle on the sling, and secure the hook by mousing.

The raising operation can now be completed. To raise an ordinary tripod, a crew of about eight maybe required. As the tripod is being lifted, spread the legs so that when it is in the upright position, the legs will be spread the proper distance apart. After getting the tripod in its final position, lash the legs near the bottom with line or chain to keep them from shifting (figure 4-40). Where desirable, a leading block for the hauling part of the tackle can be lashed to one of the tripod legs, as indicated in figure 4-40.

In erecting a large tripod you may need a small gin pole to aid in raising the tripod into position. To erect a tripod lashed according to the first procedure described in the preceding section, you first raise the tops of the legs far enough from the ground to permit spreading them apart. Use guys or tag lines to help hold the legs steady while they are being raised. Now, with the legs clear of the ground, cross the two outer legs and place the center leg so that it rests on top of the cross. Then, attach the sling for the hoisting tackle. Here, as with a small tripod, simply pass the sling over the center leg and then around the two outer legs at the cross.

SCAFFOLDING

LEARNING OBJECTIVE: Upon completing this section, you should be able to determine the proper usage of wood and prefabricated metal scaffolding.

As the working level of a structure rises above the reach of crew members on the ground or deck, temporary elevated platforms, called scaffolding, are erected to support the crew members, their tools, and materials,

There are two types of scaffolding in use today-wood and prefabricated. The wood types include the swinging scaffold, which is suspended from above, and the pole scaffold, which is supported on the ground or deck. The prefabricated type is made of metal and is put together in sections, as needed.

SWINGING SCAFFOLD CONSTRUCTION

The simplest type of a swinging scaffold consists of an unspliced plank that is made from 2-by-8-inch (minimum) lumber. Hangers should be placed between 6 and 18 inches from the ends of the plank. The span between hangers should not exceed 10 feet. Make sure that the hangers are secured to the plank to stop them from slipping off. Figure 4-42 shows the construction of a hanger with a guardrail. The guardrail should be made of 2-by-4-inch material between 36- and 42-inches high. A midrail, if required, should be constructed of 1-by-4 lumber.

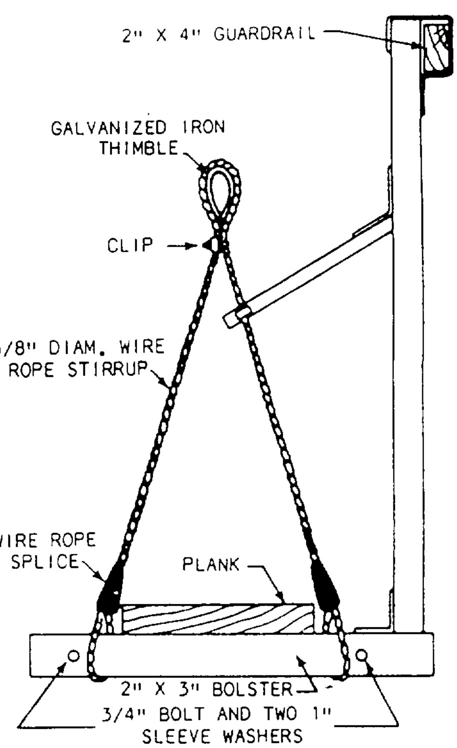

Figure 4-42.—Typical hanger to use with plank scaffold.

Swing scaffolds should be suspended by wire or fiber line secured to the outrigger beams, A minimum safety factor of 6 is required for suspension ropes, The blocks for fiber ropes should be the standard 6-inch size consisting of at least one double block and one single block. The sheaves of all blocks should fit the size of rope used.

The outrigger beams should be spaced no more than the hanger spacing and should be constructed of no less than 2-by-10 lumber. The beam should not extend more than 6 feet beyond the face of the building. The inboard side should be 9 feet beyond the edge of the building and should be securely fastened to the building.

Figure 4-43 shows a swinging scaffold that can be used for heavy work with block and tackle.

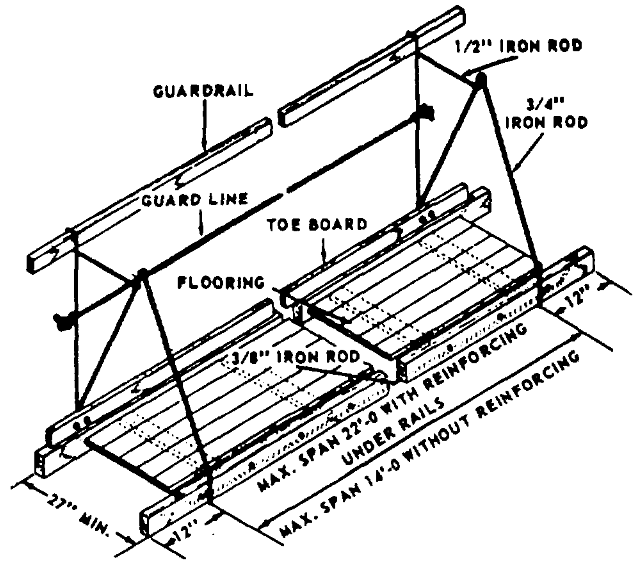

Figure 4-43.—Swinging scaffold.

POLE SCAFFOLD CONSTRUCTION

The poles on a job-built pole scaffold should not exceed 60 feet in height. If higher poles are required, the scaffolding must be designed by an engineer.

- All poles must be setup perfectly plumb.
- The lower ends of poles must not bear directly on a natural earth surface. If the surface is earth, a board footing 2-inches thick and 6- to 12-inches wide (depending on the softness of the earth) must be placed under the poles.
- If poles must be spliced, splice plates must not be less than 4-feet long, not less than the width of the pole wide, and each pair of plates must have a combined thickness not less than the thickness of the pole. Adjacent poles must not be spliced at the same level.
- A ledger must be long enough to extend over two pole spaces, and it must overlap the poles at the ends by at least 4 inches. Ledgers must be spliced by overlapping and nailing at poles—never between poles. If platform planks are raised as work progresses upward, the ledgers and logs on which the planks previously rested must be left in place to brace and stiffen the poles. For a heavy-duty scaffold, ledgers must be supported by cleats, nailed or bolted to the poles, as well as by being nailed themselves to the poles.
- A single log must be set with the longer section dimension vertical, and logs must be long enough to overlap the poles by at least 3 inches. They should be both face nailed to the poles and toenailed to the ledgers. When the inner end of the log butts against the wall (as it does in a single-pole scaffold), it must be supported by a 2-by-6-inch bearing block, not less than 12 inches long, notched out the width of the log and securely nailed to the wall. The inner end of the log should be nailed to both the bearing block and the wall. If the inner end of a log is located in a window opening, it must be supported on a stout plank nailed across the opening. If the inner end of a log is nailed to a building stud, it must be supported on a cleat, the same thickness as the log, and nailed to the stud.
- A platform plank must never be less than 2-inches thick. Edges of planks should be close enough together to prevent tools or materials from falling through the opening. A plank must be long enough to extend over three logs, with an overlap of at least 6 inches, but not more than 12 inches.

PREFABRICATED SCAFFOLD ERECTION

Several types of scaffolding are available for simple and rapid erection, one of which is shown in figure 4-44. The scaffold uprights are braced with diagonal members, and the working level is covered with a platform of planks. All bracing must form triangles, and the base of each column requires adequate footing plates for bearing area on the ground or deck. The steel scaffolding is usually erected by placing the two uprights on the ground or deck and inserting the diagonal members. The diagonal members have end fittings that permit rapid locking in position. In tiered scaffolding, figure 4-45, the first tier is set on steel bases on the ground, and a second tier is placed in the same manner on the first tier with the bottom of each upright locked to the top of the lower tier. A third and fourth upright can be placed on the ground level and locked to the first set with diagonal bracing. The scaffolding can be built as high as desired, but high scaffolding should be tied to the main structure. Where necessary, scaffolding can be mounted on casters for easy movement.

Prefabricated scaffolding comes in three categories: light, medium, and heavy duty. Light duty has nominal 2-inch-outside-diameter steel-tubing bearers. Posts are spaced no more than 6- to 10-feet apart. Light-duty scaffolding must be able to support 25-pound-per-square-foot loads.

Medium-duty scaffolding normally uses 2-inch-outside-diameter steel-tubing bearers. Posts should be spaced no more than 5- to 8-feet apart. If 2 1/2-inch-outside-diameter steel-tubing bearers are used, posts are be spaced 6- to 8-feet apart. Medium-duty scaffolding must be able to support 50-pound-per-square-foot loads.

Heavy-duty scaffolding should have bearers of 2-1/2-inch-outside-diameter steel tubing with the posts spaced not more than 6-feet to 6-feet 6-inches apart. This scaffolding must be able to support 75-pound-per-square-foot loads.

To find the load per square foot of a pile of materials on a platform, divide the total weight of the pile by the number of square feet of platform it covers.

BRACKET SCAFFOLDING

The bracket, or carpenter's scaffold (figure 4-46), is built of a triangular wood frame not less than 2- by 3-inch lumber or metal of equivalent strength. Each bracket is attached to the structure in one of four ways: a bolt (at least 5/8 inch) that extends through to the inside of the building wall; a metal stud

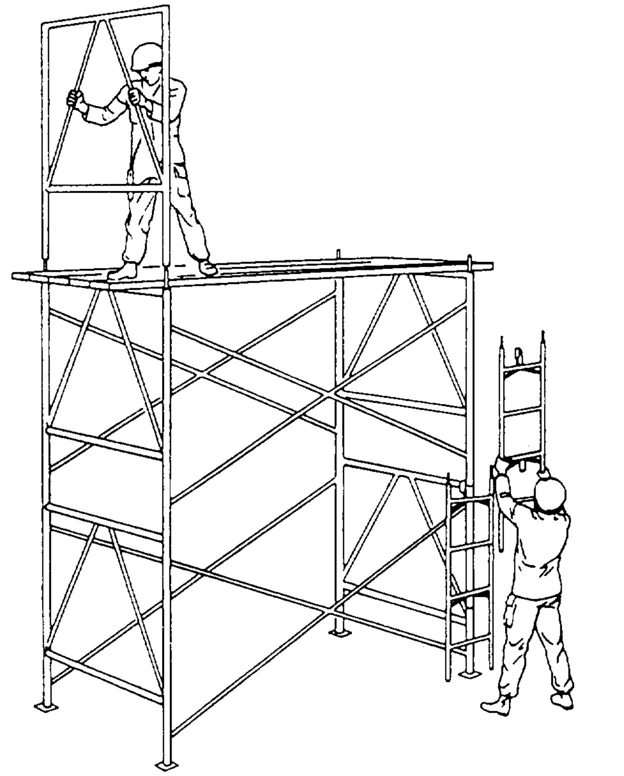

Figure 4-44.—Assembling prefabricated independent-pole scaffolding.

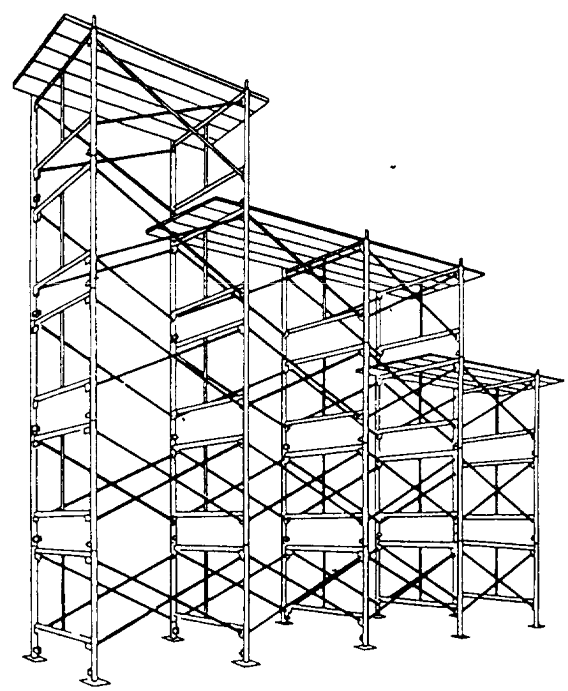

Figure 4-45.—Tiered scaffolding.

attachment device; welded to a steel tank; or hooked over a secured supporting member.

The brackets must be spaced no more than 8-feet apart. No more than two persons should be on any 8-foot section at one time. Tools and materials used on the scaffold should not exceed 75 pounds.

The platform is built of at least two 2- by 10-inch nominal size planks. The planks should extend between 6 and 12 inches beyond each support.

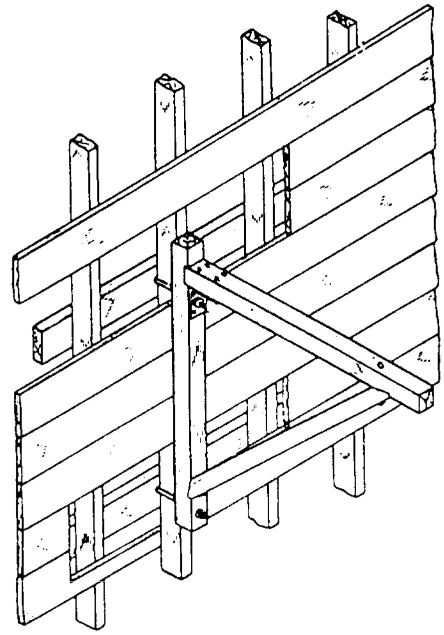

Figure 4-46.—Carpenter's portable bracket for scaffolding.

SCAFFOLD SAFETY

When working on scaffolding or tending others on scaffolding, you must observe all safety precautions. Builder petty officers must not only observe the safety precautions themselves, but they must also issue them to their crew and ensure that the crew observes them.

RECOMMENDED READING LIST

NOTE

Although the following references were current when this TRAMAN was published, their continued currency cannot be assured. You therefore need to ensure that you are studying the latest revisions.

Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat, Volume I, Office of the Chief of Naval Operations (OP-45), Washington, D.C., 1989.

Safety and Health Requirements Manual, EM 385-1-1, U.S. Army Corps of Engineers, Washington, D.C. 1981.